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THREE NEW SPECIES OF *TEMNOGAMETUM* FROM SOUTH INDIA

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The genus *Temnogametum* was established by West, W. and G. S. in 1897, on the type species *T. heterosporum* from West Central Africa. A second species, *T. uleanum*, was recorded by Möbius from Brazil in 1895. This alga was described by him as *Mougeotia uleanum* Möb. But Wille in 1909 transferred it to the genus *Temnogametum* and called it *T. uleanum* (Möb.) Wille. A third species, *T. thaxteri*, was recorded by Transeau from Trinidad in 1932. And a fourth species, *T. transeaui*, was described by Prescott (1947) from Equador. Thus the genus has been known until now only from Tropical and Subtropical South America and Tropical Africa. So far, there has been no record of any member of this interesting genus from Asia. The author recorded three new species of this genus from South India. A preliminary account of these three species was read by him in 1940 before the Botany Section of the Indian Science Congress Meeting at Madras (Iyengar, 1940, p. 129). He wanted to obtain some more material of the third species, *viz.*, *T. tirupatiense*, in order to observe some more stages in it. Unfortunately he was not able to get any further material of the alga. As there is no point in waiting any further, he decided to publish his full paper with what observations he was able to make on the alga. A full account of the three species is given here below.

Temnogametum indicum sp. nov.

This alga was growing in a tiny water channel about two feet wide and about two to six inches deep in an open scrub jungle near Tambaram, sixteen miles South of Madras.* The alga grows in trailing strands attached to the stems of grasses and other objects in the flowing water.

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* The author is indebted to Prof. T. N. Venkatanathan, formerly of the Presidency College, Madras, for very kindly placing his formalin material of the alga at the author's disposal.

It could be easily distinguished in the field from the other algæ growing along with it by its dark purple colour. The cells of the alga are purple-coloured owing to the colour of the cell-sap. This purple colour is retained for some time even after preservation in 4% formalin. The colour is ultimately lost in the preserved material after some time.

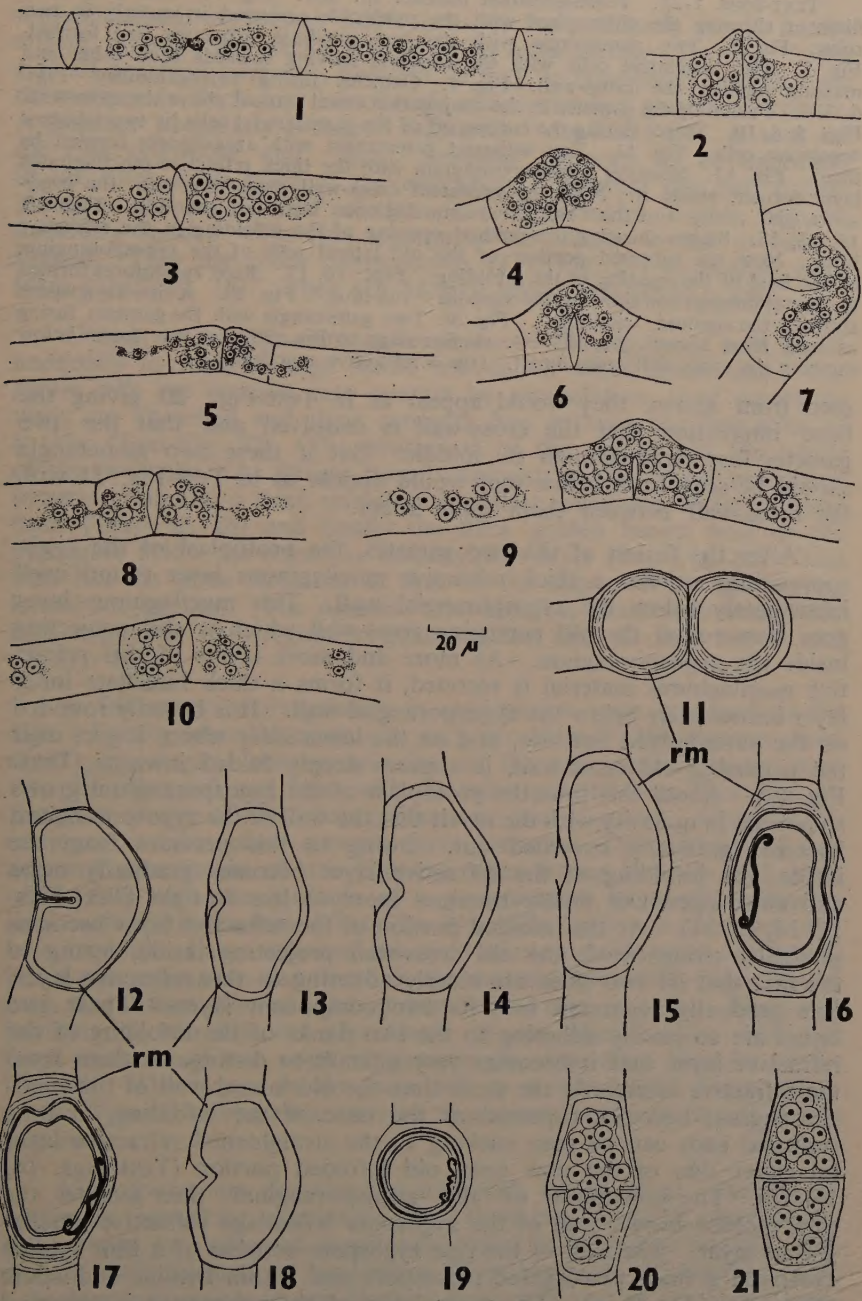
The cells of the alga are 19–23 μ broad and 3–12 times as long as broad. The chloroplast is flat and ribbon-shaped and contains 8 to 32 pyrenoids arranged irregularly in two rows (Text-Fig. 1). The chloroplast is bright green in colour but its green colour is masked by the purple colour of the cell-sap.

Sexual Reproduction

Sexual reproduction takes place both by lateral and scalariform conjugation, the former being the more common.

The details connected with lateral conjugation and zygospore formation are rather interesting and so are described at some length below. The contents of two neighbouring cells begin to move slowly towards each other and become gradually massed against the septum separating the two cells (Text-Fig. 3). A short cell is then cut off on either side of the septum so that each of the two vegetative cells is divided unequally into a short cell with rich contents (gametangium) and a long cell with poor contents (sterile cell) (Text-Fig. 10). The way in which the two new walls cut off the gametangial cells is also interesting. These walls grow centripetally inwards and when nearly complete cut through the massed protoplast, so that the major portion of the protoplast goes into the shorter gametangial cell, while the remaining very small portion goes into the longer sterile cell (Text-Figs. 5, 8, 10). Text-Fig. 5 shows the stage just before the wall cuts through the protoplast. Möbius (1895) also has given a figure of a similar stage in *T. uleanum* which has been reproduced by Printz (1927, Fig. 281 A), Transeau (1932, Fig. 1) and Kolkwitz and Krieger (1941, Fig. 190).

The adjacent ends of the two adjoining gametangia then become gradually beaked on one side into two papillate processes in close contact with each other (Text-Fig. 2). The two papillæ fuse and an open communication is established between the two gametangia at this region. The old septum between the gametangial cells, however, remains quite intact. The contents of the two gametangia then fuse through the opening (conjugation canal) formed above the cross-wall (Text-Figs. 6, 7, 9). At the same time the outer walls of the fused gametangia become bulged out. As a result of this bulging on one side, the filament becomes slightly geniculate on the opposite side (Text-Fig. 7). Soon the fused protoplast occupies the whole space inside the two cells which now become the zygosporangium, but the old cross-wall between the cells is not dissolved but persists projecting inside the zygosporangial cavity (Text-Figs. 6, 7, 9). If the two conjugating gametangia shown in Text-Figs. 4, 6, 7, 9, should be



TEXT–FIGS. 1–21

TEXT-FIGS. 1–21. *Temnogametum indicum* sp. nov. Fig. 1. Two cells of a filament showing the chloroplast with the pyrenoids arranged irregularly in two rows. Fig. 2. Two gametangia with the two papillate processes just formed. Fig. 3. Two vegetative cells with the contents moving towards each other and massing against the cross-wall. Fig. 4. Gametes fusing anisogamously. Figs. 6, 7, 9. Fusion of the gametes in the conjugation canal formed above the cross-wall. Figs. 5, 8, 10. Stages during the cutting off of the gametangial cells by two adjacent vegetative cells. Fig. 11. Two adjacent gametangia with azygospores formed by them. Fig. 12. Showing a zygosporangium with the thick refractive mucilaginous layer formed inside it. Note the persistent cross-wall projecting into the zygosporangial cavity and the refractive mucilaginous layer all round it. Figs. 13, 14, 15, 18. Stages showing the gradual opening of the infolding in the refractive layer. Note the ruptured portion of the old lateral wall of the zygosporangium at the base of the opening of the infolding. Figs. 16, 17. Ripe zygospores formed by lateral conjugation showing the sigmoid "riss-linie". Fig. 19. A ripe azygospore showing the sigmoid "riss-linie". Fig. 20. Two gametangia with the gametes fusing as seen from above. Fig. 21. A similar stage to Fig. 20, but seen from below showing the cross-wall quite intact. (*rm* = refractive mucilage.)

seen from above, they would appear as in Text-Fig. 20 giving the false impression that the cross-wall is dissolved and that the two gametes fuse right through its middle. But if these two gametangia should be seen from below they would appear as in Text-Fig. 21 with the cross-wall between them quite intact.

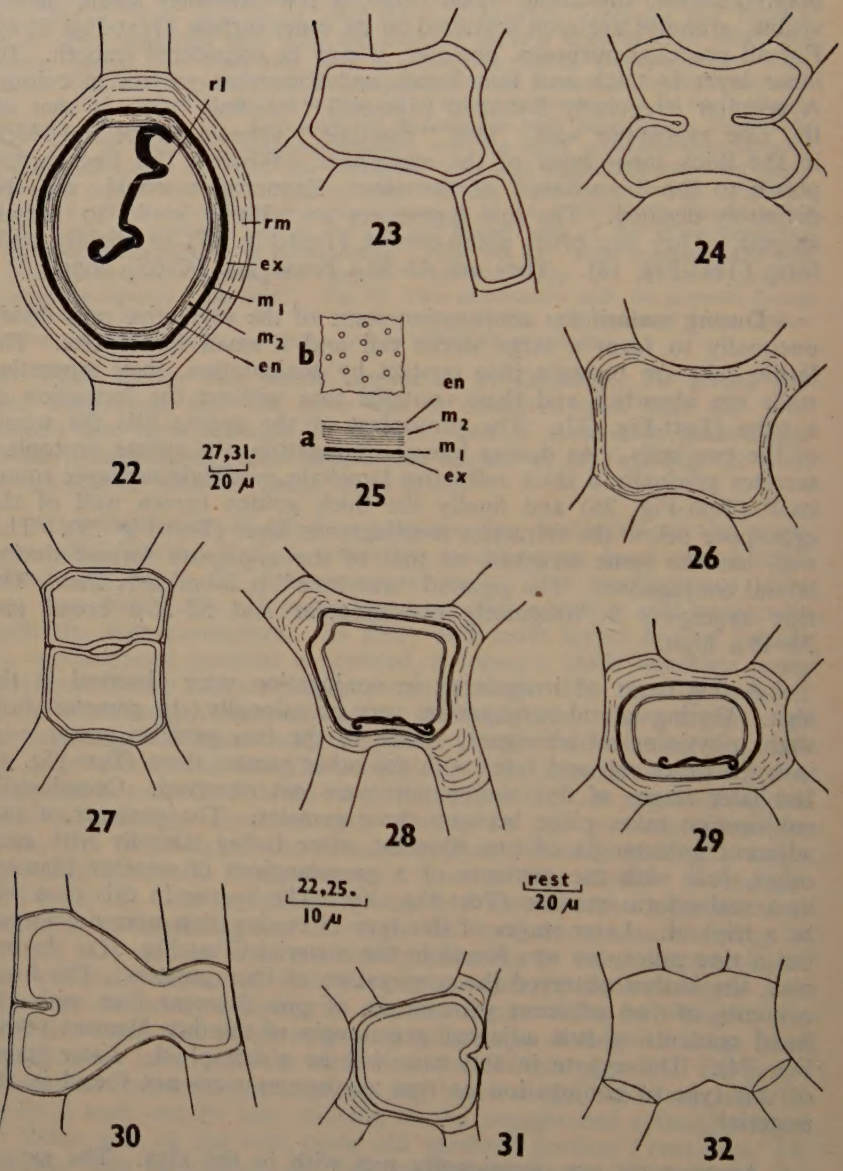
After the fusion of the two gametes, the protoplast of the zygosporangium secretes a thick refractive mucilaginous layer round itself immediately below the zygosporangial wall. This mucilaginous layer goes even round the old persisting cross-wall which is still projecting inside the zygosporangium. As more and more layers of this refractive mucilaginous material is secreted, it forms a thick lamellate inner layer immediately below the zygosporangial wall. It is broadly rounded on the outer bulged out side, and on the lower side, where it goes over the persisting old cross-wall, it appears deeply folded inwards (Text-Fig. 12). About this time the protoplast of the zygosporangium grows somewhat in quantity with the result that the wall of the zygosporangium becomes gradually stretched out. Owing to this pressure from the inside, the infolding of the refractive layer becomes gradually more and more open and finally becomes more or less straight (Text-Figs. 13, 14, 15, 18). As the infolded portion of the refractive layer becomes gradually straightened, the old cross-wall projecting inside, owing to the fact that its two sides are closely adhering to this refractive layer, gets gradually separated into its two component layers. These two layers are so closely adhering to the two flanks of the infolding of the refractive layer that it becomes very difficult to distinguish them from the refractive layer. At the same time the old lateral wall of the zygosporangium becomes ruptured at the base of the infolding, and its ruptured ends can be seen sticking to the straightened refractive layer on either side of the now open old infolded portion (Text-Figs. 14, 15, 18). The protoplast of the zygosporangium then secretes the thick golden brown wall of the zygospore below the refractive mucilaginous layer. The wall of the ripe zygospore consists of a thin hyaline exospore, a thick two-layered mesospore and a thin hyaline endospore (Text-Figs. 22, 25 *a*). The outer layer of the mesospore is firm and golden brown in colour. It appears smooth, but, under very high

magnifications, say about 3,000 times, a few extremely small, hardly visible, granules are seen scattered on its outer surface (Text-Fig. 25 *b*). For all practical purposes, however, it may be considered smooth. Its inner layer is thick and lamellated, and somewhat greyish in colour. A peculiar irregularly S-shaped (sigmoid) " riss-linie " (?) is seen on the ripe zygospore wall. This " riss-linie " appears to be imbedded in the thick inner layer of the mesospore. Whether this line corresponds to the " riss-linie " of the other Zygnemales could not be definitely decided. The ripe zygospores are elliptic ovoid to barrel-shaped. They are often plano-convex (Text-Fig. 17) or slightly reniform (Text-Fig. 16). They are 42–50 μ broad and 60–65 μ long.

During scalariform conjugation some of the vegetative cells divide unequally to form a large sterile cell and a small fertile one. The fertile cells are brought into contact by geniculation, their separating walls are absorbed and their contents fuse without the formation of a tube (Text-Fig. 32). The protoplast of the zygote fills the whole of the two cells. As during lateral conjugation, the zygote protoplast secretes gradually a thick refractive lamellate mucilaginous layer round itself (Text-Fig. 26) and finally the thick golden brown wall of the zygospore below the refractive mucilaginous layer (Text-Fig. 28). This wall has the same structure as that of the zygospore formed during lateral conjugation. The sigmoid " riss-linie " is found here also. The ripe zygospore is irregularly quadrangular and 52–56 μ broad and 35–45 μ high.

A few cases of irregularity in conjugation were observed in the alga. During lateral conjugation, very occasionally, the gametes show slight physiological anisogamy. One of the two gametes passes over into the other cell and fuses with the other gamete there (Text-Fig. 4). But later stages of this conjugation were not observed. Occasionally conjugation takes place between three gametes. The contents of two adjacent gametangia of one filament, after fusing laterally with each other, fuse with the contents of a gametangium of another filament in a scalariform manner (Text-Fig. 30). The zygote in this case will be a triploid. Later stages of this type of conjugation were not found, but a ripe zygospore was found in the material (Text-Fig. 31). In one case, the author observed the conjugation of four gametes. The fused contents of two adjacent gametangia of one filament fuse with the fused contents of two adjacent gametangia of another filament (Text-Fig. 24). The zygote in this case will be a tetraploid. Later stages of this type of conjugation or ripe zygospores were not found in the material.

Azygospores are occasionally met with in the alga. The azygospores are formed by gametangia when there is a failure of conjugation. In one case, two adjacent gametangia failed to conjugate laterally, but each of them formed an azygospore (Text-Fig. 11). In another case, a single gametangium of one filament fused with one of a pair of gametangia in another filament. The second gametangium of the pair which failed to conjugate formed an azygospore (Text-Fig. 23). In



TEXT-FIGS. 22–32. *Temnogametum indicum* sp. nov. Fig. 22. A zygospore formed by lateral conjugation. Figs. 23, 26, 27, 28, 29, 32. Scalariform conjugation. Fig. 23. A gametangium of one filament fused with one of a pair of gametangia from another filament. The second gametangium of the pair has become an azygosporangium. Fig. 27. Two zygosporangia formed side by side. Figs. 28, 29. Zygosporangia with ripe zygospores. Note sigmoid "riss-linie" on the zygospore wall. Fig. 24. Conjugation between four gametangia. Fig. 30. Conjugation

between three gametangia. Fig. 31. Ripe zygospore formed by conjugation of three gametangia. Fig. 25 *a*. Zygospore-wall highly magnified showing optical median section. Fig. 25 *b*. Outer layer of mesospore highly magnified in surface view showing the scattered round granules on it. (*rm* = refractive mucilage; *ex* = exospore; m_1 = outer layer of mesospore; m_2 = inner lamellated layer of mesospore; *en* = endospore; *rl* = riss-linie).

still another case, an azygospore was formed by a solitary gametangium in a filament. This azygospore was quite ripe and its wall had the same structure as that of a ripe zygospore with the characteristic sigmoid " riss-linie " (Text-Fig. 19).

The present alga differs from all the four previously described species. In *T. heterosporum* the filaments are 14–17 μ broad and its chloroplasts have 2–6 pyrenoids arranged in a single row. In *T. uleanum* the filaments are 10–12 μ broad and the chloroplasts have only 4 pyrenoids arranged in a single row. In *T. thaxteri*, the filaments are 39–45 μ broad and its chloroplasts have 30–120 pyrenoids irregularly scattered throughout. In *T. transeaui* the filaments are 14–20 μ broad and its chloroplasts have only 2–4 pyrenoids arranged in a single row. In the present alga, the filaments are 19–23 μ broad and its chloroplasts have 8–32 pyrenoids irregularly arranged in two rows. The present alga differs from *T. heterosporum* and *T. uleanum* in having broader filaments and a larger number of pyrenoids in its chloroplasts. It differs from *T. thaxteri* in having narrower filaments and a smaller number of pyrenoids in its chloroplasts. It comes near *T. transeaui* in the breadth of its filament, but differs from it in having a larger number of pyrenoids in its chloroplasts, and also in having the pyrenoids arranged not in a single row as in *T. transeaui*, but in two rows. The present alga therefore appears to be a new species and may be called *Temnogametum indicum* sp. nov.

***Temnogametum indicum* sp. nov.**

Vegetative cells 19–23 μ broad and 3–12 times as long as broad; chloroplast plate-shaped with 8–32 pyrenoids irregularly arranged in two rows; cell-sap in living specimens purple in colour; conjugation, both lateral and scalariform, the former more common; gametangia 19–23 $\mu \times$ 20–25 μ; zygospores by lateral conjugation elliptic ovoid to barrel-shaped with rounded or truncate ends, often plano-convex or slightly reniform; zygospores 42–50 μ broad and 60–65 μ long; zygospores by scalariform conjugation irregularly quadrangular and 52–56 μ broad and 35–45 μ high; zygospore-wall three layered; mesospore thick, smooth and orange golden brown in colour; riss-linie in zygospore-wall sigmoid.

Habitat: In a small channel in the scrub jungle near Tambaram, South of Madras (T. N. Venkatanathan).

Cellulæ vegetativæ 19–23 μ latæ, 3–12 plo. longiores quam latæ; Chloroplastum platellæ simile, pyrenoideis 8–32 irregulariter dispositis in seriem duplicem; cellulæ succus in cellulis viventibus purpureus colore; conjugatio tum lateralis tum scalariformis, prior frequentior; gametangia 19–23 $\mu \times$ 20–25 μ; zygosporæ ex conjugatione laterali

elliptico-ovoideæ vel doliiformes, apicibus rotundatis vel truncatis, sæpe plano-convexæ vel tenuiter reniformes 42–50 μ latæ, 60–65 μ longæ; zygosporæ ex conjugatione scalariformi irregulariter quadrangulares, 52–56 μ latæ, 35–45 μ altæ; zygosporarum parietes 3-seriati; mesosporium crassum, leve, aurantiace aureo-brunneum colore; linea rupturæ in parietibus zygosporarum sigmoidea.

Typus lectus in canali parvulo in silva depauperata ad Tambaram, in India meridionali a T. N. Venkatanathan, et positus in herbario proprio auctoris sub numero 100.

***Temnogametum cylindrosporum* sp. nov.**

This alga was found growing on *Utricularia* sp. along with *Spirogyra*, *Zygnema* and other algæ in a stream in the Western Ghats region in Coimbatore District.* The filaments are 43–48 μ broad and about 4 to 8 times as long as broad. The chloroplast is ribbon-shaped and contains 10 to 18 pyrenoids arranged in a single row (Text-Figs. 38, 39).

Reproduction

The only method of reproduction observed in the alga is by azygospores. The azygospores are formed in the following manner. In a vegetative cell the contents gradually move to one side and become massed against the end wall. The portion of the cell containing the greater portion of the massed protoplast is then cut off by a wall into a short cell, so that the old vegetative cell becomes divided unequally into a short cell with rich contents and a long cell with poor contents. The short cell becomes the gametangium and the long cell the sterile cell. The wall which cuts off the gametangium in the vegetative cell grows centripetally inwards as in *T. indicum* and cuts the protoplast into two (Text-Fig. 34). A single azygospore is formed in each gametangium. The protoplast of the young gametangium first of all secretes a thick refractive mucilaginous layer round itself immediately below the wall of the gametangium. The gametangial protoplast then secretes the wall of the azygospore immediately below the refractive mucilaginous layer. The ripe azygospore wall is thick and smooth and consists of three layers, a thin hyaline exospore, a thick mesospore and a thin hyaline endospore. The mesospore is smooth and is made up of two layers, a thick greyish lamellated inner layer and a thinner but firm golden brown outer layer (Text-Figs. 33, 35). The characteristic S-shaped (sigmoid) " riss-linie " is seen on the mesospore as in *Temnogametum indicum*. The azygospore is oblong-cylindrical in shape with the terminal ends depressed and deeply concave (Text-Figs. 33, 35, 36, 37). The side walls also are slightly concave. The azygospores are 43–49 μ broad and 50–65 μ long. Occasionally two gametangia are formed side by side in pairs but no conjugation takes place between them. Each of these two gametangia forms an azygospore (Text-Fig. 36).

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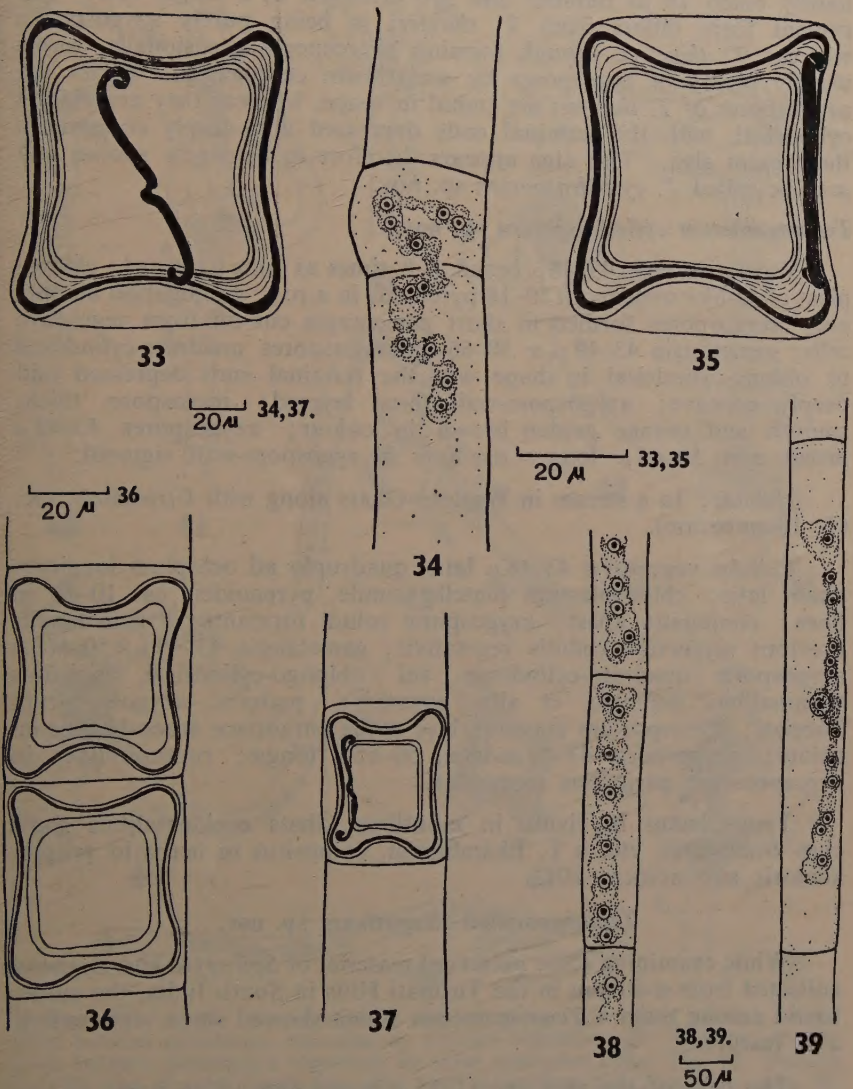
* The author is indebted to the late Dr. T. Ekambaram, Professor of Botany, Presidency College, Madras, for material of this alga.



TEXT-FIGS. 33–39. *Temnogametum cylindrosporum* sp. nov. Figs. 33, 35, 37. Ripe azygospores showing the sigmoid "riss-linie". Fig. 36. Two azygospores formed side by side (Sigmoid "riss-linie" not shown). Fig. 34. A gametangium being cut off from a vegetative cell by a centripetally growing wall. Fig. 38. Cells showing chloroplast in surface view. Fig. 39. Cell showing chloroplast in side-view.

This alga in its dimensions comes very near to *Temnogametum thaxteri* Transeau (1932, p. 489), but differs from it in several respects. The pyrenoids in *T. thaxteri* are 30–120 in number and are scattered

throughout the chloroplast, whereas in the present alga the pyrenoids hardly reach 18 in number and are arranged in a single row. The present form differs from *T. thaxteri* in being purely azygosporic, whereas *T. thaxteri*, though forming azygospores occasionally, forms usually plenty of zygospores by scalariform conjugation. Again the azygospores of *T. thaxteri* are tumid in shape, whereas they are oblong cylindrical, with the terminal ends depressed and deeply concave in the present alga. This alga appears therefore to be a new species and may be called *T. cylindrosporum* sp. nov.

***Temnogametum cylindrosporum* sp. nov.**

Vegetative cells 43–48 μ broad, 4–8 times as long as broad; chloroplast plate-like with about 10–18 pyrenoids in a row; conjugation absent; only azygospores formed in short gametangia cut off from vegetative cells; gametangia 43–49 $\mu \times$ 50–66 μ; azygospores quadrate-cylindrical to oblong-cylindrical in shape with the terminal ends depressed and deeply concave; azygospore-wall three layered; mesospore, thick, smooth and orange golden brown in colour; azygospores 43–49 μ broad and 50–65 μ long; riss-linie in zygospore-wall sigmoid.

Habitat: In a stream in Western Ghats along with *Utricularia*, etc. (T. Ekambaram).

Cellulæ vegetativæ 43–48 μ latæ, quadruplo ad octoplum longiores quam latæ; chloroplastum platellæ simile, pyrenoideis ca. 10–18 in linea; conjugatio abest; azygosporæ solum formantur e gametangiis brevibus sejunctis a cellulis vegetativis; gametangia 43–49 $\mu \times$ 50–66 μ; azygosporæ quadrato-cylindricæ vel oblongo-cylindricæ, apicibus terminalibus depressis et alte concavis; parietes azygosporarum 3-seriati; mesosporium crassum, leve atque aurantiace aureo-brunneum colore; azygosporæ 43–49 μ latæ, 50–65 μ longæ; rupturæ linea in zygosporarum parietibus sigmoidea.

Typus lectus in rivulo in montibus Ghats occidentalibus simul cum *Utricularia*, etc. a T. Ekambaram, et positus in herbario proprio auctoris sub numero 101.

***Temnogametum tirupatiense* sp. nov.**

While examining some preserved material of *Spirogyra* and *Zygnema* collected from a stream in the Tirupati Hills in South India, the author found among them a *Temnogametum* which showed some very remarkable features.*

The cells of the alga are 11–13 μ broad and 12–16 times as long as broad. The chloroplast is narrow and ribbon-shaped with 10–15 pyrenoids placed in a row. The cell-wall is thin and covered by a thin layer of mucilage.

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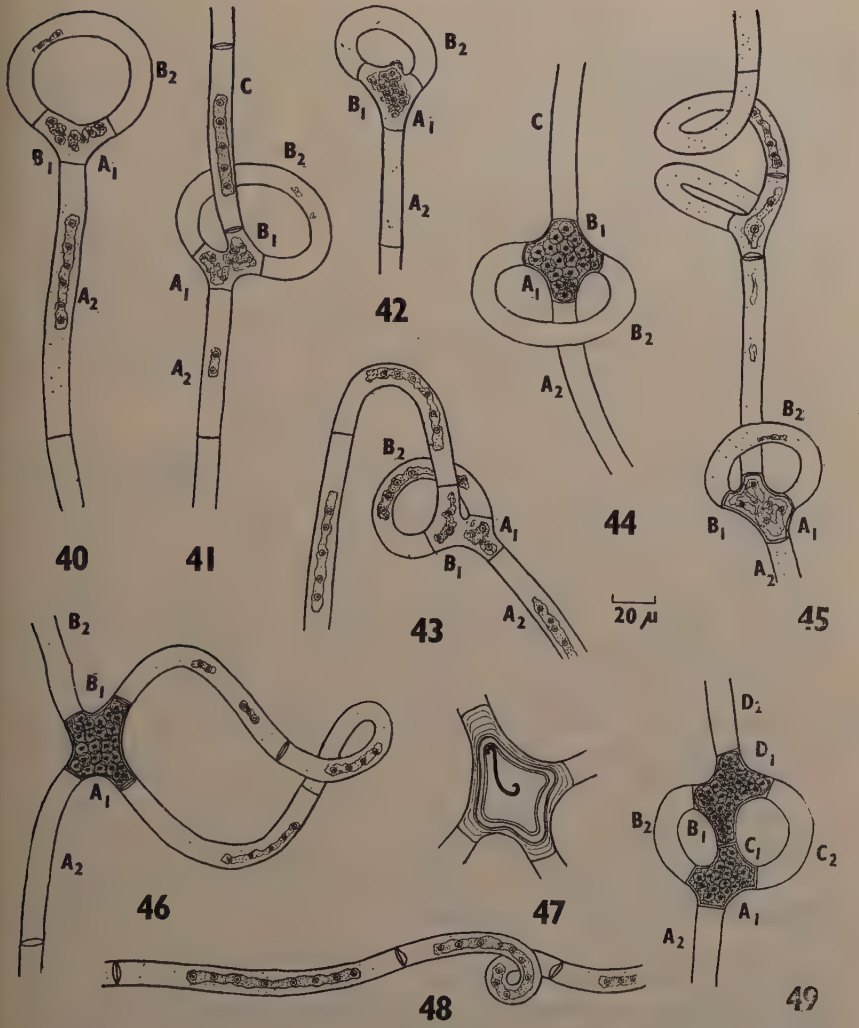
* The author is indebted to Prof. M. S. Raghavachari of St. Berchmann's College, Chenganacherry, Travancore, for material of the alga. The author's thanks are also due to Miss V. K. Kamalam who sent him some material of this alga from Trivandrum later on.



TEXT-FIGS. 40–49. *Temnogametum tirupatiense* sp. nov. Figs. 40–45. Conjugation between gametangia separated by a single vegetative cell. Fig. 46. Conjugation between gametangia separated by three vegetative cells. Fig. 48. Portion of a filament showing vegetative cells with chloroplast and pyrenoids. Fig. 49. Portion of a filament where the coiling is somewhat intricate involving the conjugation of two pairs of gametangia; A_1 conjugates with C_1 and B_1 conjugates with D_1. (C = Vegetative cell· A_2, B_2, C_2, D_2 = Sterile cells· A_1, B_1, C_1, D_1 = Gametangial cells.)

Sexual Reproduction

The alga is monœcious and conjugation takes place between gametangia formed on the same filament. In the four previously recorded species of *Temnogametum* and also in *T. indicum*, lateral conjugation takes place between two gametangia situated adjacent to each

other on the same filament as in Text-Fig. 51. But in the present alga, the two conjugating gametangia do not lie side by side, but are separated from each other by one or more sterile or vegetative cells. This is due to the fact that when two adjacent vegetative cells cut off each a short gametangial cell, the two gametangial cells lie, not adjacent to each other as in the other species, but away from each other separated by a sterile cell, as in Text-Figs. 40–45, or by one or more vegetative cells which do not cut off gametangial cells, as in Text-Fig. 46. During conjugation the two gametangia therefore are brought into contact with each other by a coiling of the portion of the filament between them. The intermediate coiling portion may consist of only one sterile cell or may consist of one sterile cell and one or more vegetative cells. The coiling may often be very intricate and involve the conjugation of two or more pairs of gametangia (Text-Fig. 49). How the gametangia cells are cut off and the conjugation between them is brought about are shown in their simplest form in Text-Figs. 52–55.

During conjugation the walls of the two conjugating gametangia become attached together without producing any conjugating processes and the contents of the two gametangia fuse after the dissolution of the portion of the walls between them. Soon after the fusion of the two protoplasts, the zygosporangial protoplast first of all secretes a thick refractive mucilaginous layer round itself and then secretes the wall of the zygospore. The zygospores were not fully ripe in the material, but a few ripe zygospores were found after careful search. The wall of the ripe zygospore is thick golden brown and smooth and consists of three layers, a thin hyaline exospore, a thick golden brown mesospore and a thin hyaline endospore. The zygospores are four-sided with rounded corners, and are 40–45 μ across. The characteristic sigmoid " riss-linie " is seen in the ripe zygospore-wall (Text-Fig. 47).

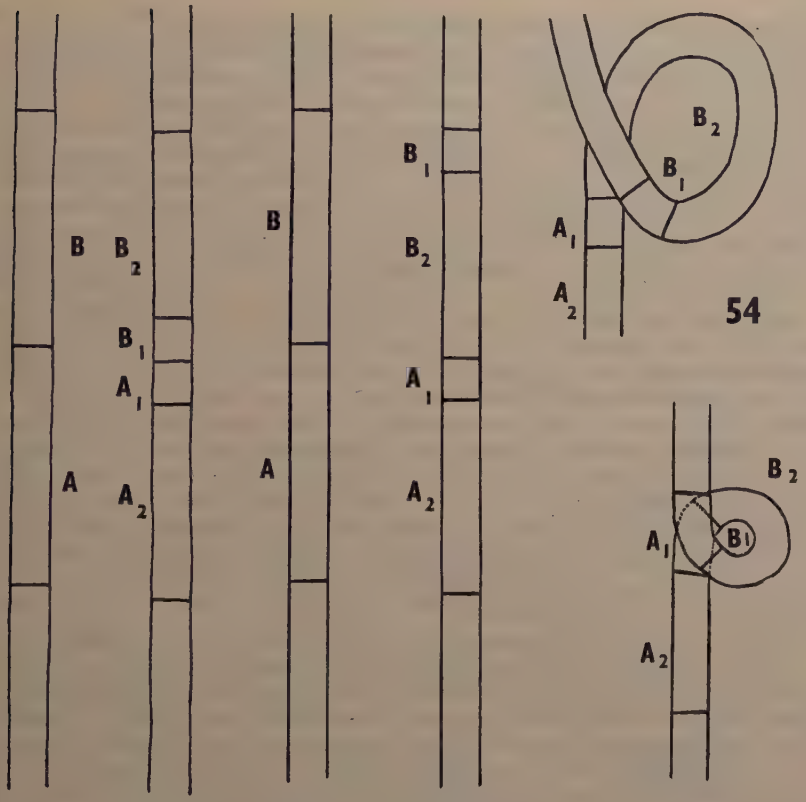
Several instances of scalariform conjugation also were observed in the material. These are evidently due to the gametangia of opposite sexes of two separate filaments coming into contact with each other.

***Temnogametum tirupatiense* sp. nov.**

Vegetative cells 11–13 μ broad and 12–16 times as long as broad; chloroplast narrow plate-shaped with 10–15 pyrenoids in a row; filaments monœcious, conjugation unique in being brought about between gametangia situated apart from each other in the same filament, through the coiling of the intervening portion of the filament; gametangia 11–13 $\mu \times$ 12–15 μ; zygospores about 40–45 μ in diameter; zygospore-wall three-layered; mesospore thick orange golden brown; "riss-linie" in zygospore-wall sigmoid.

Habitat: In a hill stream at Tirupati, South India (M. S. Raghavachari); also from Trivandrum, Kerala State (Miss V. K. Kamalam).

Cellulæ vegetativæ 11–13 μ latæ, duodecies ad sexdecies longiores quam latæ; chloroplastum angustum platellæ simile, pyrenoideis 10–15 in linea; filamenta monoica, conjugatio singularis in eo quod efficitur inter gametangia inter se distantia in eodem filamento, per spiralem



TEXT-FIGS. 50–55. *Temnogametum;* lateral conjugation. Figs. 52–55. Schematic respresentation of a simple case of conjugation between gametangia in *T. tirupatiense* where the gametangia are not lying side by side but are separated by a single vegetative (sterile) cell. Figs. 50, 51. Schematic representation of the conjugation between two gametangia lying side by side as in other species of *Temnogametum.* (*A*, *B* = Vegetative cells. A_1, B_1 = Gametangial cells. A_2, B_2 = Sterile cells.)

contractionem partis intermediæ filamenti; gametangia 11–13 $\mu \times$ 12–15 μ; zygosporæ diametientes ca. 40–45 μ; parietes zygosporarum 3-seriati; mesosporium crassum, aurantiace luteo-brunneum; linea rupturæ in parietibus zygosporarum sigmoidea.

Typus lectus in rivulo collino ad Tirupati, in India meridionali a M. S. Raghavachari; lectus etiam ad Trivandrum in Statu Kerala a dna. V. K. Kamalam, et positus in Herbario proprio auctoris sub numero 102.

DISCUSSION

All the authors who have dealt with *Temnogametum* state that during lateral conjugation in *Temnogametum* the gametes fuse after

the wall separating the two gametangia is dissolved completely. Czurda (1932, p. 98) in his description of *Mougeotia uleana* Möbius [= *Temnogametum uleanum* (Möb.) Wille] states " Die seitliche Kopulation erfolgt nach vollständiger Auflösung der Zellquerwand ". And, in his description of *Mougeotia heterospora* (W. and G. S. West) Czurda (= *Temnogametum heterosporum* W. and G. S. West), he states " Seitliche Kopulation nach Auflösung der Zellquerwand ". Transeau (1932, p. 488) states that during lateral conjugation in *Temnogametum* the primary wall separating the two gametangia is dissolved and then the two gametes fuse. Kolkwitz and Krieger (1941, p. 197) also state " Die querwand wird ..... ganz aufgelöst ". The author's careful study of all the stages of lateral conjugation in *T. indicum* shows that the cross-wall separating the two gametangia is not dissolved at any stage during the conjugation. The two gametes fuse through an opening (conjugation canal), formed *above* the cross-wall by the fusion of the walls separating the two papillæ. The cross-wall is not dissolved, but remains projecting inside the zygosporangium and the gametes fuse round the cross-wall as in the other Zygnemales generally. The figures of lateral conjugation in *T. heterosporum* given by W. and G. S. West show clearly that the cross-wall is not dissolved during the conjugation, but remains projecting inside the zygosporangium (W. and G. S. West, 1897, Pl. 370, Figs. 7 and 9; Transeau, 1932, Pl. I, Figs. 9, 10 and 11; Kolkwitz and Krieger, 1941, Figs. 194 and 196). Unfortunately the figure given by W. and G. S. West for lateral conjugation in *T. heterosporum* in a later paper on the Conjugatæ (W. and G. S. West, 1898, Pl. V, Fig. 52) is very misleading, and gives the very wrong impression that the cross-wall is dissolved in the middle and that the gametes fuse right through its centre. This figure really shows the two conjugating cells as seen from above (see p. 206 and Text-Figs. 20 and 21 of the present paper). These two conjugating cells when seen from the side will appear as in Figs. 7 and 9 of their 1897 paper with the cross-wall quite intact and projecting inside the zygosporangial cavity. This figure of W. and G. S. West (1898, Pl. V, Fig. 52) is very probably responsible for the present general impression that the cross-wall in *Temnogametum* dissolves completely before the gametes fuse during lateral conjugation.

Fully ripe zygospores were not known for a long time in *Temnogametum*. Recently ripe zygospores were described in *T. transeaui* by Prescott (1947, p. 132, Pl. I, Figs. 3 and 6). The present study adds three more species in which ripe zygospores (or azygospores) are known.

The most interesting feature of the zygospore-wall is the presence of a peculiar sigmoid " riss-linie ". This sigmoid " riss-linie " is found in the wall of the ripe azygospores also. The exact nature of this sigmoid "riss-linie" is not quite clear. Whether the sigmoid "riss-linie" corresponds to the " riss-linie " of the other Zygnemales could not be definitely decided. The " riss-linie " in the zygospore-wall of the Zygnemales represents the line of opening of the zygospore-wall during its germination. It would be interesting to know if this sigmoid "riss-linie"

represents the place of opening of the zygospore-wall during its germination and, if so, how the opening takes place. This is the first time that a sigmoid " riss-linie " is recorded in the zygospore-wall of the Zygnemales. Prescott (1947) does not refer to any such sigmoid " riss-linie " in his description of the zygospore-wall in *T. transeaui*. It would perhaps be worth while examining the zygospores of this species again to find out if any sigmoid " riss-linie " is present in its wall. If this sigmoid " riss-linie " should be found in the zygospore-wall of *T. transeaui* also, we may perhaps then be justified in considering it as an important generic feature of *Temnogametum*.

A word may be said here about the splitting of the transverse septum observed during lateral conjugation in *T. indicum*. This is a very rare phenomenon among the Zygnemales. Splitting of the transverse septum into its two component layers during lateral conjugation was recorded in *Mougeotia adnata* by Iyengar (1932, p. 272, G. I). And a study of the figures of *Zygnema czurdæ* Randh. (Randhawa, 1936, Figs. 4, 6), *T. uleanum* (Wille, 1909, Fig. 3, B, C), and *T. transeaui* (Prescott, 1947, Figs. 2, 4, 5), suggests that splitting of the transverse septum into its two component layers takes place during lateral conjugation in these three algæ also.

Key to the Species of *Temnogametum*

1. Chloroplasts with pyrenoids in one row . . 2
1. Chloroplasts with pyrenoids irregularly in two rows . . . . . *T. indicum*
1. Chloroplasts with scattered pyrenoids . . *T. thaxteri*
   2. Filaments coiling during conjugation . . *T. tirupatiense*
   2. Filaments not coiling during conjugation . . 3
3. Reproduction by azygospores (zygospores not known) . . . . . *T. cylindrosporum*
3. Reproduction by zygospores. 4
   4. Cell-diameter 10–12 μ, zygospores (lateral conjugation) 20–40 $\mu \times$ 40–60 μ . . *T. uleanum*
   4. Cell-diameter 14–17 μ, zygospores (lateral conjugation) 20–26 $\mu \times$ 61–67 μ . . *T. heterosporum*
   4. Cell-diameter 14–20 μ, zygospores (lateral conjugation) 35–42 $\mu \times$ 80–100 μ . . *T. transeaui*

Summary

The genus *Temnogametum* W. and G. S. West is a rare one and has been so far recorded only from Central Africa and South America. Three new species of this interesting genus are recorded from South India, *viz.*, *T. indicum*, *T. cylindrosporum* and *T. tirupatiense*.

The structure and reproduction of these three new species are described in full detail in the paper. In *T. indicum* reproduction takes

place both by lateral conjugation and scalariform conjugation. In *T. cylindrosporum* reproduction takes place only by azygospores. In *T. tirupatiense* the conjugation is very peculiar. The filaments are monœcious, but the conjugating gametangia do not lie side by side as in the other species of *Temnogametum*, but are separated by one or more vegetative cells. During conjugation the two gametangia are brought together by a coiling of the portion of the filament between them.

There is at present a general impression that during lateral conjugation in *Temnogametum* the wall separating the two gametangia is dissolved completely before the two gametes fuse. This impression is shown to be wrong, since the wall separating the two gametangia is not at all dissolved, but persists projecting inside the zygosporangium when the two gametes fuse.

Nothing was known previously regarding the stages leading to the formation of the ripe zygospores in *Temnogametum*. A detailed account is given in the present paper of all the stages in *T. indicum* leading to the formation of the ripe zygospores.

A peculiar sigmoid " riss-linie " (?) is found in the wall of the ripe zygospores and azygospores. The exact nature of this sigmoid " riss-linie " is not clear. Whether it corresponds to the " riss-linie " of the other Zygnemales could not be definitely decided. This is the first record of a sigmoid " riss-linie " in the wall of the ripe zygospores and azygospores in the Zygnemales.

A key to the species of *Temnogametum* is given.

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SPORE CONTENT OF AIR OVER THE MEDITERRANEAN SEA*

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Introduction

Presence of characteristic spore and pollen population in the air over inland agricultural and industrial areas has long been recognised. The recent work of Pady and Kelly (1953) and Pady and Kapika (1955) using aeroplanes proved the existence of fungus spores in the upper layers of air over the Arctic and the Atlantic Oceans. Miquel (1876) was the first to investigate whether or not micro-organisms are found in the lower layers of the sea air. Using an aspirator worked by suction off condensor of the engine of the ship, he took samples at a level of 10 metres above the floating line of the ship, during a voyage to Canaries from Paris. He found that sea rapidly purified contaminated air and wind at a distance beyond 100 Km. from the shore was almost perfectly pure. These results led him to the conclusion that large bodies of water become an absolute obstacle to the spread of infectious diseases through air. The quantitative data collected by Hesselman (1919) indicate how with the increase in distance from the land, decrease in the number of pollen grains of certain pines is brought about. Erdtman (1937) trapped pollen grains by means of vacuum cleaners during a voyage from Gothenburg to New York. His results showed that pollen grains per 100 cubic metres of air declined from 18·0 in North Sea to 0·7 in mid-ocean and rose to 6·0 off New Foundland, fell to 3·5 south of Nova Scotia and finally rose to 15·0 off the coast of New England, while his records for experiments conducted on the top of a water tower in Vasteras about 110 Km. west of Stockholm showed an average of 18,000 pollen grains per 100 m.^{3} of air. The results obtained by Bisby (1935) using Petri-dishes as spore traps in a voyage from Montreal to London, convinced him that micro-organisms are so scarce over the oceans as to necessitate special arrangements for long exposure of plates and slides. The introduction of volumetric suction air sampling methods (Hirst, 1952; Gregory, 1954) have now made it possible to get a quantitatively and qualitatively complete picture of the spore content of air at any locality and it is considered worthwhile to sample air over oceans employing a volumetric suction trap to gather more information on the spore content of the sea air.

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Methods

With the kind permission of the Penninsular and Oriental Steam Navigation Company, Ltd., London, and the co-operation of the Commander and the officers of the ship, arrangements were made on the Passenger ship S. S. Strathmore for running a spore trap during a voyage from London to Bombay scheduled to go through the Suez Canal during October-November 1956. Due to the 'Suez crisis' the route of the ship was changed when she was in the Mediterranean Sea. From there she was diverted to Malta and after a stay of nearly two days in the Malta Harbour, she was taken back to Gibralter and reached Bombay *via* Cape of Good Hope. During this journey air was sampled from Gibralter to Malta, Malta to Gibralter and Gibralter to Las Palmas. On the 'bridge' of the ship at a height of 70 ft. above the sea-level, air was sampled at a rate of 10 litres per minute using the 'Impactor unit' of Gregory's (1954) Portable Volumetric Spore Trap. The 'Impactor unit' was connected to the suction port of an 'Edwards R. B. 4 pump and compressor' run with a D.C. motor. The flow rate was regulated by the use of an 'Orifice-plate' with a narrow bore, the size of which was adjusted to allow a flow rate of 10 l./min. which was placed in the rubber tubing connecting the 'Compressor' and the 'Impactor unit'. The slides which were prepared according to the method described by Gregory (1954) were changed often and were mounted in 'Solvar'. Due to the presence of less number of spores on the trace, the entire trace was examined under the oil immersion objective to count the number of each 'Spore type' caught on the slide. The number counted was then converted into an estimated number of spores per cubic metre of air. Identification of spores was based on the spore morphology alone and the categories of the 'spore types' chosen are 'form groups' devised (as was done by Hirst, 1953; Gregory and Hirst, 1957; Gregory and Sreeramulu, 1958 and Sreeramulu, 1956) after comparison with many reference slides of carefully identified spores. Those not included in any named group were counted under one group: 'Unclassified'.

Results

The slides were changed often to see whether there is any relation between the time of the day and the number and the types of spore population present in the air. In Table I the serial numbers of the slides along with the dates and the times at which they were changed are given in columns 1, 2 and 3. In the other columns data showing the position of the ship at the beginning and the end of exposure of each slide, the distance travelled during the time of exposure, distance to the nearest land, wind direction and speed, and the wet and dry bulb readings taken from the ship's records are presented. In Table II the estimated number per cubic metre of air for the spore types included in this study are given along with the volume of air sampled with each slide. To get a comparative idea about the changes, the time of the day, distance to the nearest land and wind direction are also included in the table.

TABLE I

Data giving the position of the ship, time of air sampling, wind and other factors prevailing during the period of exposure of each slide in the trap

Slide No.	Date	Time of exposure		Position of the ship		Distance travelled (miles)	Distance from the nearest land (miles)	Wind		Onshore or Offshore	Dry bulb	Wet bulb	Remarks
		Time on	Time off	At on	At off			Velocity (knots)	Direction				
1	October 29	4-30 P.M.	5-30 P.M.	36 08 N 04 48 W	36 10 N 04 25 E	..	20—21	18	..	Offshore	63	56	
2	30	10-40 A.M.	12-40 P.M.	36 45 N 02 00 E	36 47 N 02 24 E	..	10	7	..	Parallel to shore	68	59	
3	30	12-40 P.M.	3-05 P.M.	36 50 N 02 45 E	36 30 N 03 45 E	42	7—4	9	NW	Onshore	67	60	
4	30—31	9-05 P.M.	6-45 A.M.	37 11 N 05 57 E	37 30 N 09 45 E	190	12—25	5	W	Parallel to shore	64	59	
5	31	7-35 A.M.	12-00 Noon	37 19 N 10 39 E	36 50 N 12 00 E	87	4—16	13	S	Offshore	67	60	
6	31	12-05 P.M.	6-30 P.M.	36 50 N 12 00 E	36 10 N 14 00 E	115	4—8	11	SE	Offshore	72	60	
7	31	6-45 P.M.	? (Before 8 P.M.)	36 50 N 12 05 E	..	30	5	2	Var.	Variable	71 at Noon	76	
8	November 1	8-30 A.M.	4-35 P.M.	..	..	..	..	2	Var.	Variable	81	75	Ship moored in the Malta Harbour
9	1	4-40 P.M.	5-50 P.M.	..	..	..	..	5	SW	..	75	72	,,
10	1—2	8-55 P.M.	7-45 A.M.	..	..	..	..	13	S	..	72	66	,,

11	2	7-50 A.M.	10-30 A.M.	36 00 N 14 40 E	36 00 N 14 15 E	48	1—20	13	S	Offshore	68	62	Leaving Malta Harbour
12	2	10-30 A.M.	2-35 P.M.	36 00 N 14 15 E	36 50 N 12 20 E	76	15	13	NWN	Offshore	66	62	
13	2	2-35 P.M.	4-35 P.M.	36 50 N 12 20 E	36 55 N 11 30 E	38	20	13	WNW	Offshore	65	62	
14	2	4-35 P.M.	10-55 P.M.	36 55 N 11 30 E	37 22 N 09 22 E	120	5	30	WNW	Offshore	64	58	
15	2—3	11-00 P.M.	8-20 A.M.	36 50 N 01 00 E	37 13 N 05 58 E	171	5—30	30	W	Parallel to shore	60	56	
16	3	8-25 A.M.	11-00 A.M.	37 13 N 05 58 E	37 10 N 04 30 E	45	20—10	21	W	..	59	57	Rain
17	3	3-00 P.M.	11-00 P.M.	36 55 N 03 04 E	36 40 N 00 20 E	152	8—5	18	W	Parallel to shore	62	56	Rain
18	3—4	11-00 P.M.	11-00 A.M.	36 40 N 00 20 E	36 16 N 04 50 W	238	20—50	7	W	..	64	58	
19	4	11-05 A.M.	9-00 P.M.	36 16 N 04 50 W	35 43 N 06 07 W	65	5—0·5	5	W	Offshore	62	57	Reached Gibralter and inside the harbour
20	4—5	9-05 P.M.	9-45 A.M.	35 43 N 06 07 W	32 59 N 09 34 W	228	10—30	4	NE	Offshore	64	58	Left Gibralter Harbour
21	5	9-50 A.M.	9-15 P.M.	32 59 N 09 34 W	30 13 N 13 10 W	230	50	3	NE	Offshore	69	63	
22	5—6	9-20 P.M.	? (About 5-30 A.M.)	30 13 N 13 10 W	31 50 N 16 00 W	171	30—1	4	NE	Offshore	67	62	Reached Las Palmas Harbour
23	6	7-30 A.M.	..	..	..	..	..	4	NE	Onshore	69	64	Inside Las Palmas Harbour

TABLE

Estimated number per cubic metre of air of the

Slide No.	Date	Time of exposure		Volume of air sampled (cubic meters)	Distance to the nearest land (miles)	Wind direction (onshore or offshore)
		Time on	Time off			
	October					
*1	29	4-30 P.M.	5-30 P.M.	0·60	20—21	Off.
2	30	10-40 A.M.	12-40 P.M.	1·20	10	Parallel
3	30	12-40 P.M.	3-05 P.M.	1·45	7—4	On.
4	30—31	9-05 P.M.	6-45 A.M.	5·80	12—25	Parallel
5	31	7-35 A.M.	12-00 Noon	2·65	4—16	Off.
6	31	12-05 P.M.	6-30 P.M.	3·85	4—8	Off.
7	31	6-45 P.M.	? (About 7-45 P.M.)	?0·60	5	Var.
	November					
8	1	8-30 A.M.	4-35 P.M.	4·85	Inside Malta Harbour	Var.
9	1	4-40 P.M.	5-50 P.M.	0·70	do.	..
10	1—2	8-55 P.M.	7-45 A.M.	6·50	do.	..
11	2	7-50 A.M.	10-30 A.M.	1·60	Leaving Malta Harbour	Off.
12	2	10-30 A.M.	2-35 P.M.	2·45	15	Off.
13	2	2-35 P.M.	4-35 P.M.	1·20	20	Off.
14	2	4-35 P.M.	10-55 P.M.	3·80	5	Off.
15	2—3	11-00 P.M.	8-20 A.M.	5·60	5—30	Parallel
16	3	8-25 A.M.	11-00 A.M.	1·55	20 -10	..
*17	3	3-00 P.M.	11-00 P.M.	4·80	8—5	Parallel
*18	3—4	11-00 P.M.	11-00 A.M.	7·20	20—50	..
19	4	11-05 A.M.	9-00 P.M.	5·95	5—0·5	Off.
20	4—5	9-05 P.M.	9-45 A.M.	7·60	10—30	Off.
21	5	9-50 A.M.	9-15 P.M.	6·85	50	Off.
22	5—6	9-20 P.M.	? (About 5-30 A.M.)	? 4·90	30—1	Off.
*23	6	7-30 A.M.	..	..	Inside Las Palmas Harbour	..

* Counts not taken as the trace on the slide is damaged during the transit.

II

various spore types together with some relevant data

Estimated number per cubic metre of air of the various spore types																Totals		
Cladosporium	Smuts	Red-brown basidiospores	Yellow basidiospores	*Alternaria*	*Stemphylium*	*Epicoccum*	*Periconia*	*Helminthosporium*	Coloured bicelled spores	'*Fumago*' type	Septate fusiform spores	*Torula herbarum*	*Nigrospora*	Uredospores	*Curvularia*	Unclassified	Fungus spores	Pollens	Hyphal fragments
34·2	5·9	12·5	0·8	4·2	..	..	0·8	..	7·5	..	5·0	2·5	0·8	0·8	..	18·4	95·0	3·3	3·3
1·6	25·2	4·2	1·4	6·3	1·4	0·7	0·7	..	2·1	7·0	0·7	..	..	..	..	18·0	83·5	0·7	7·6
12·9	6·7	5·4	1·6	0·7	0·3	0·2	..	0·3	2·1	1·2	0·5	0·2	0·7	..	..	3·1	35·5	0·2	0·9
12·1	4·2	15·0	2·3	6·4	1·5	0·8	..	..	6·4	..	..	1·9	..	..	..	23·8	74·5	2·6	3·4
10·4	2·6	6·3	1·1	5·7	0·8	..	..	..	5·2	0·5	..	..	0·3	0·3	..	10·0	44·0	0·3	4·4
15·1	1·7	10·0	1·7	1·7	1·7	..	..	1·7	8·4	..	..	..	..	..	..	10·0	53·5	1·7	..
2·1	17·7	12·2	2·1	9·3	8·2	..	1·7	2·1	..	2·3	..	0·1	..	..	0·8	15·7	91·0	16·6	?
28·6	18·5	50·0	12·9	7·1	8·5	1·4	..	..	..	..	5·7	..	..	..	1·4	7·4	222·0	7·1	?
3·7	2·3	14·8	1·2	7·7	2·3	..	..	0·8	6·2	3·1	0·6	0·5	0·6	..	0·5	10·0	62·0	6·5	?
25·3	3·8	9·4	1·3	12·5	2·5	..	..	5·0	..	1·3	1·3	1·3	..	..	..	27·2	109·0	16·9	?
21·6	3·7	4·5	2·9	0·4	..	0·4	..	0·4	..	..	0·8	0·8	..	..	0·4	4·9	43·5	2·9	2·9
19·2	4·2	1·7	3·3	0·8	0·8	0·8	..	..	0·8	..	0·8	..	1·7	..	..	6·7	40·7	1·7	2·5
17·1	..	2·4	1·9	0·8	..	..	1·5	..	..	..	..	0·5	..	..		15·3	41·0	0·3	1·6
3·6	0·4	0·7	0·4	0·2	..	..	..	..	..	0·4	..	..	0·2	..	..	3·6	9·3	0·5	0·7
11·0	..	1·9	1·9	..	..	..	..	..	..	..	..	..	..	..	..	12·9	27·4	..	2·5
35·4	1·6	5·9	1·4	4·6	1·5	0·8	2·4	0·8	0·7	1·5	0·8	0·7	1·7	..	..	21·7	106·0	4·1	10·2
45·0	12·2	4·8	1·7	6·9	0·5	1·1	0·8	0·4	4·4	0·5	0·5	0·7	6·9	0·8	0·1	28·3	138·0	1·6	8·0
4·3	1·3	1·3	0·3	0·4	0·3	..	..	..	0·3	0·5	..	..	..	..	..	5·4	14·3	2·5	0·3
3·5	11·6	0·8	2·0	0·2	0·6	..	0·6	..	1·2	0·2	0·6	..	..	..	..	3·7	29·0	0·4	2·7

Discussion

The results presented in Table II confirm the presence of a variety of fungus spores and pollen grains in the lower layers of the sea air upto a distance of about 50 miles away from the coastline, the quantities of each spore type varying with the distance to the nearest land. When the ship was moored inside the harbours of Malta and Gibralter concentrations of about 200/m.^{3} were observed, but when she was travelling at about a distance of 50 miles from the shore concentrations of about 14/m.^{3} were noticed. As was recorded by Rittenberg (1939) for air over a portion of the Pacific Ocean, here also a gradual decrease in the concentration of the various spore types was noticed with increase in distance from the nearest land.

Of the many types of spores and pollen grains caught from the sea air, spores of the *Cladosporium* type and the coloured basidiospores occurred in comparatively higher numbers than those of many crop pathogens. (Highest concentrations recorded during the entire period: Coloured basidiospores—62/m.^{3}; *Cladosporium* type—45/m.^{3}; *Ustilago* type—25/m.^{3}; *Alternaria* type—12/m.^{3} and *Helminthosporium* type—5/m.^{3}) Pollens were present throughout the whole period in very low concentrations with an average value of about 4/m.^{3} while the corresponding value for the total number of fungus spores was about 70/m.^{3}

The use of the Automatic Volumetric Spore Trap (Hirst, 1952) has revealed (Hirst, 1953; Gregory and Sreeramulu, 1958) the existence of different characteristic spore loads during day and night times in inland temperate areas. To find out whether the spore types occurring in the sea air also exhibit any such periodicity, slides were changed often. Spore types which are known to exhibit their peak concentrations during the daytime on land (*Cladosporium* type, *Alternaria* type, etc.) were observed to occur in higher concentrations during daytimes than during night times in the sea air, but basidiospores and the like which are known to occur in higher concentrations during the night times on land, were not found in significantly higher numbers during night times in the sea air. As atmospheric turbulence is a major factor responsible for the dispersal of spores in the air, probably the absence of higher concentrations of the spore types which are known to possess distinct nocturnal spore discharging habit, might be due to the low state of turbulence in the air at the time of their discharge on land. After dawn on land atmospheric turbulence begins to increase and reaches a maximum by about noon when buoyancy effects also are known to predominate. Under these conditions rapid spread of the spores in the air takes place. This explains why *Cladosporium* type and the like occurred in sea air in higher concentrations during daytime while basidiospores which are usually found in higher numbers during the night time on land when turbulence is very low, did not show considerable increase in their numbers during night time.

Comparison of the spore content of the sea and land air shows that plant spores occur in very low concentrations in sea air and that

almost all the spores caught from the atmosphere above the sea are of terrestrial origin. The observed gradual decrease in concentration of these spores with increase in distance from the shore indicates that oceans of large size like the Pacific, the Atlantic and the Indian Oceans probably serve as effective barriers for the long distance dissemination of air-borne spores.

Summary

Pollen and fungus spore content of the air 70 ft. above the sea-level, over a part of the Mediterranean Sea was studied employing a suction trap during a voyage in October-November 1956. A variety of fungus spores and pollen grains of terrestrial origin showing a gradual decrease in their concentrations with increase in distance upto 50 miles from the shore were found. The changes in concentrations of 18 spore types were recorded. The significance of the data was discussed.

Acknowledgements

I wish to acknowledge my indebtedness to the authorities of the Penninsular and Oriental Steam Navigation Company, London, for permission to do this work and for the facilities given to me for the running of the spore trap on their ship, S. S. Strathmore during my return voyage to India. My special thanks are due to the Commander of the ship, Capt. W. H. C. Wood-Roe, R.D., R.N.R., and the Chief Officer for their co-operation and help in many ways. My thanks are also due to Mr. J. J. Shaw, Second Officer, for placing the ship's weather and other records at my disposal.

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ON THE GRASSES OF PARASNATH (BIHAR)

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(Received for publication on January 7, 1958)

The Parasnath Hill is noted for its peculiar floristic elements. It has been botanized by several workers in the past, especially Hooker (1848), Thompson, Edgeworth, Anderson (1863), Clarke, Prain (1903), Haines (1921–25) and others.

Recent publications by Srivastava (1955), Mehta (1956) and Mukerjee (1956) have further advanced our knowledge regarding the climatic and floristic features of this area.

Amongst the several families of the Flowering Plants and Ferns, that enter into the composition of the Parasnath Flora, Gramineæ seems to be dominant. Seventy-nine species of grasses have been reported from this area by Haines (1924), Srivastava (1955) and Mukerjee (1956).

In October 1956 a party of plant collectors led by Mr. V. Chandra was sent to Bihar from the National Botanic Gardens, Lucknow, in search of economic plants. They also visited the Parasnath Hill and made several gatherings of plant specimens. A set of grasses was studied by the author. This collection contains eleven grass species which were not previously recorded from the Parasnath Hill. This brings up the total number of known grasses from this region to 90. However, this number should not be regarded as final, for it is possible that more grasses may be discovered in near future in this area. An analysis of the various taxa of Gramineæ represented within the area is given below:—

On analysing the composition and distribution of the grass flora of the Parasnath, one is led to the following conclusions:—

1. The tropical element is very well developed and claims the highest number of species.

2. The Mediterranean and the cosmopolitan elements are poorly developed; the former is represented by *Pennisetum orientale* Rich., *Aristida depressa* Retz., *Desmostachya bipinnata* Stapf, *Heteropogon contortus* R. and S., etc., and the latter by the following weeds: *Polypogon monspeliensis* Desf., *Eragrostis* spp., *Setaria glauca* Beauv., *Cynodon dactylon* Pers., etc.

3. Temperate grasses are few.

4. Alpine and endemic ones are absent.

Sub-fam. Pooideæ			Sub-fam. Panicoideæ		
Tribes	No. of Gen.	No. of Spp.	Tribes	No. of Gen.	No. of Spp.
Bambuseæ ..	2	2	Paniceæ ..	9	22
Eragrosteæ ..	6	13	Andropogoneæ ..	27	40
Sporoboleæ ..	1	2	Maydeæ ..	1	1
Chlorideæ ..	2	2			
Agrosteæ ..	2	2			
Stipeæ ..	1	1			
Oryzeæ ..	1	1			
Zoysieæ ..	1	1			
Thysanolæneæ ..	1	1			
Arundinelleæ ..	1	2			
TOTAL ..	18	27	TOTAL ..	37	63

5. Some species like *Setaria palmifolia* Stapf, *Garnotia stricta* Brongn., *Indochloa clarkei* Bor, *Arthraxon serrulatus* Hochst., *Themeda villosa* Dur. et Jack., *Tripogon capillatus* Jaub. and Spach. and *Dendrocalamus sericeus* Munro, are mainly confined to the Parasnath Hill in Bihar.

NEW RECORDS FROM PARASNATH HILLS

Eleven species of grasses are listed below and the specimens referred to are lodged in the Herbarium, National Botanic Gardens, Lucknow.

1. *Arundinella pumila* (Hochst.) Steud.

Syn. *A. tenella* Nees et Wt.

Near Dak Bungalow, 1,400 m. *V. Chandra and Party* no. 33420. Also near the top of the hill *V. Chandra and Party* no. 33462.

Distribution.—The Upper Gangetic Plain, Bihar, Assam, Bombay, Madras; also in Burma, Ceylon and up to Philippines.

2. *Cenchrus pennisetiformis* Hochst. & Steud.

Syn. *Pennisetum cenchroides* Rich. var. *echinoides* Hook. f.

Parasnath Hill, without exact elevation, *Srivastava*, no. 21340.

Distribution.—Punjab, the Upper Gangetic Plain, Bombay and Madras; also in Arabia, Africa and Madiera.

3. *Chloris dolichostachya* Lagasca

Syn. *C. incompleta* Roth.

Parasnath Hill 1,033 m. *V. Chandra and Party* no. 34314, A.

Distribution.—Plains of India, Afghanistan, China and Ceylon.

4. *Digitaria longiflora* (Retz.) Pers.

Parasnath Hill about 1,000 m. *V. Chandra and Party* no. 34312.

Distribution.—The Upper Gangetic Plain, Bihar, Bengal, Bombay, Madras; also in Ceylon and Burma.

5. *Eleusine indica* Gaertn.

Slopes south of the Jal Mandir, 1,250 m. *V. Chandra and Party*, no. 33863.

Distribution.—Punjab, the Upper Gangetic Plain, Bihar, Bengal, Bombay, Madras; also in other tropical countries of the Old World.

6. *Eragrostis unioloides* (Retz.) Nees ex Steud.

Parasnath Hill, without exact elevation. *Srivastava* no. 20537.

Distribution.—Kashmir, Punjab, the Upper Gangetic Plain, Bihar, Bengal (?), Assam, Burma, South India and several other countries of Tropical Asia.

7. *Eragrostis coarctata* Stapf. ex Hook. f.

Parasnath Hill, without exact elevation. *Srivastava* no. 20786.

Distribution.—The Upper Gangetic Plain, Bihar, Assam, Madhya Pradesh and Madras; also in Burma.

8. *Eulalia trispicata* (Schult.) Henr.

Syn. *Eulalia argentea* Brongn.

Pollinia argentea Trin.

Slopes south of Jal Mandir, 1,250 m. *V. Chandra and Party*, no. 33637.

Distribution.—Tropical Himalayas, Bihar, Assam, Burma, Bombay, Madras; also in Ceylon, Malaya and Australia.

9. *Pennisetum pedicellatum* Trin.

Collected from the vicinity of Jal Mandir, 1,333 m. *V. Chandra and Party* no. 33968.

Distribution.—The Upper Gangetic Plain, Rajasthan, Bihar and Madras; also in Tropical Africa.

10. *Sporobolus indicus* R. Br.

From the vicinity of the Dak Bungalow, *V. Chandra and Party* no. 33467. Known only from Manbhum (Haines, 1924) and "Sarwada, South Ranchi" (Mooney, 1950).

Distribution.—Tropical Himalayas (up to 2,500 m.) Bihar, Assam (up to 1,500 m.), Madras and Bombay.

11. *Themeda quadrivalvis* O. Ktze.

Parasnath Hill, without exact elevation, *Srivastava* no. 20581.

Distribution.—Kumaon, the Upper Gangetic Plain, Madras, Bombay and Burma; also in Mascarene Islands.

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CARBON-NITROGEN METABOLISM OF SOIL-FUNGI

VI. Amino Acid Composition of *Fusarium vasinfectum*

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Introduction

In spite of the extensive data on the chemical composition of microbial cells, information concerning microbial proteins, which are of major importance among cellular constituents is scanty and in part inaccurate. This has been due primarily to inadequate and unreliable analytical methods for the determination of amino acids. But recently simple as well as reasonably accurate methods (chromatography, microbiological assay) have become available. This has made possible the estimation of amino acids of some of the micro-organisms.

Buchanan and Fulmer (1928) has reviewed earlier work on the amino acids in bacteria, yeasts and fungi, while subsequent work has been noticed by Camien, Salle and Dunn (1945) and Venkataram (1957).

In this paper are presented the results of studies of *Fusarium vasinfectum* on the effect of the age of culture and of the nature of the carbon source incorporated in the medium on the quantitative amino acid composition of cellular protein and its culture filtrate.

Materials and Methods

The strain of *Fusarium vasinfectum*, cultural methods and the composition of the medium are the same as in the previous investigation (Natarajan, 1958). The carbon and nitrogen sources are respectively sucrose or fructose and sodium nitrate. The circular paper chromatographic technique (Giri and Rao, 1952 *a*, *b*) is adopted for the identification of amino acids and the quantitative procedure is that of Rao and Wadhwani (1955). Two dimensional chromatography is used to confirm the identity of some of the amino acids like γ-aminobutyric acid and other ninhydrin positive substances (Williams and Kirby, 1948). The samples for the determination of free and bound amino acids of the mycelium and its culture filtrate are prepared according to the method of Pillai and Srinivasan (1956). Total nitrogen in the culture filtrate and in the mycelium are estimated by micro-kjeldahl procedures.

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Data and Discussion

The amounts of free and bound amino acid present in the mycelium of *Fusarium vasinfectum* during different stages of growth are represented in Tables I and II. It may be observed therefrom that glutamic and aspartic acids are present in high concentrations, an observation consistent with the well-known facts about other organisms and the role assigned to these amino acids in the synthesis of other amino acids. The detection of γ-aminobutyric acid is particularly interesting since information on the decarboxylation of amino acids in fungi is scanty and its presence has to be postulated to a decarboxylation of glutamic acid. It is worthy of note that free amino acids and bound amino acids present are qualitatively the same irrespective of the carbon sources tested, but vary quantitatively with the age of culture and the carbon sources. Thus it would seem from evidence adduced that cellular protein of *F. vasinfectum* has qualitatively fixed amino acid composition during its active phase of growth whether the carbon source supplied in the medium is sucrose or fructose. The concentrations of free amino acids however tend to increase or remain stationary till the 16th day and diminish to a large extent by the 20th day. The culture filtrate, it may be interesting to note, has at that time a maximum concentration of amino acids (Table III). The fall in concentrations of free amino acids during the later stages of growth may be attributed to the appearance of toxic metabolic products and the changes in pH not to mention the possibility that the amino acids may, at this stage, be utilized for synthesis of protein and/or other nitrogenous substances. It is also likely that the mycelium gets autolysed. In general, catabolism of amino acids does not correspond to anabolism of amino acids during later stages of growth. This view is supported by the finding of a decrease in nitrogen per cent. in the mycelium against an increase in the residual nitrogen in the culture filtrate (Fig. 1). The level of nitrogen in the mycelium tends to decrease with age, indicating thereby that older cultures contain less active protoplasm than young cultures. Apparently, nucleoprotein and other vital nitrogenous compounds of the cell are actively synthesized during the early and rapid stages of growth upto the 16th day under the conditions described. Thereafter, perhaps, only reserve carbonaceous materials of a storage or fibrous cell-wall type are formed resulting in an overall reduction of the nitrogen content of the cell as such.

Summary

The amino acid compositions of the mycelium of *F. vasinfectum* and its culture filtrate during different stages of growth have been determined. This was found to vary with the age of culture, but independent of the two carbon sources tested. Autolysis of the culture has been indicated to be rapid during the later stages of growth during which occurs a decrease in mycelial nitrogen commensurate with an increase of residual nitrogen in the filtrate.

TABLE I

Amino acid composition of F. vasinfectum *mycelium grown on fructose nitrate medium at different intervals of incubation*

(Amino acids are expressed as g. amino acid/100 g. dry mycelium)

Amino acids	Free amino acids					Bound amino acids				
	Days of incubation					Days of incubation				
	4	8	12	16	20	4	8	12	16	20
Glycine	0·024	0·046	0·058	0·066	0·014	0·046	0·038	0·051	0·020	0·018
Alanine	0·061	0·082	0·091	0·109	0·017	0·072	0·050	0·062	0·075	0·016
Valine	0·017	0·037	0·047	0·054	0·013	0·026	0·037	0·042	0·050	0·016
Leucine	0·018	0·043	0·055	0·075	0·012	0·032	0·046	0·028	0·020	0·012
Iso-leucine	0·019	0·040	0·052	0·081	0·014	0·042	0·059	0·018	0·042	0·016
Serine	0·012	0·031	0·046	0·076	0·019	0·040	0·060	0·072	0·026	0·014
Threonine	0·016	0·037	0·049	0·064	0·014	0·030	0·012	0·046	0·056	0·014
Cystine	0·017	0·031	0·044	0·071	0·016	..	..	..	..	..
Aspartic acid	0·118	0·140	0·160	0·190	0·014	0·120	0·088	0·096	0·100	0·016
Glutamic acid	0·110	0·145	0·171	0·210	0·015	0·110	0·120	0·085	0·076	0·014
Lysine	0·020	0·044	0·070	0·095	0·014	0·036	0·051	0·028	0·061	0·016
Arginine	0·018	0·039	0·055	0·072	0·016	0·024	0·040	0·035	0·060	0·014
Phenylalanine	0·019	0·041	0·058	0·079	0·015	0·030	0·018	0·044	0·053	0·016
Tyrosine	0·016	0·036	0·049	0·064	0·016	0·029	0·040	0·051	0·041	0·012
γ–Aminobutyric acid	0·014	0·034	0·042	0·050	0·014	0·043	0·030	0·020	0·018	0·012

TABLE II

Amino acid composition of F. vasinfectum *mycelium grown on sucrose-nitrate medium at different intervals of incubation*

(Amino acids are expressed as g. amino acid/100 g. dry mycelium)

Amino acids	Free amino acids					Bound amino acids				
	Days of incubation					Days of incubation				
	4	8	12	16	20	4	8	12	16	20
Glycine ..	0·015	0·035	0·054	0·066	0·012	0·036	0·020	0·042	0·051	0·015
Alanine ..	0·040	0·051	0·060	0·074	0·014	0·042	0·026	0·034	0·042	0·012
Valine ..	0·014	0·034	0·042	0·056	0·018	0·020	0·036	0·024	0·020	0·016
Leucine ..	0·015	0·030	0·040	0·046	0·012	0·026	0·012	0·048	0·052	0·012
Iso-leucine ..	0·016	0·029	0·038	0·044	0·016	0·032	0·020	0·051	0·063	0·013
Serine ..	0·010	0·026	0·040	0·051	0·012	0·046	0·016	0·041	0·056	0·012
Tnreonine ..	0·014	0·034	0·046	0·058	0·014	0·024	0·034	0·026	0·039	0·014
Cystine ..	0·014	0·026	0·038	0·049	0·017	..	..	..	..	..
Aspartic acid ..	0·090	0·110	0·125	0·130	0·014	0·100	0·109	0·129	0·132	0·013
Glutamic acid ..	0·100	0·109	0·124	0·140	0·016	0·121	0·100	0·134	0·098	0·012
Lysine ..	0·015	0·026	0·041	0·056	0·014	0·024	0·036	0·042	0·031	0·016
Arginine ..	0·016	0·034	0·049	0·064	0·012	0·022	0·016	0·034	0·042	0·020
Phenylalanine ..	0·017	0·026	0·041	0·054	0·012	0·020	0·032	0·040	0·036	0·010
Tyrosine ..	0·014	0·032	0·049	0·054	0·016	0·019	0·025	0·015	0·042	0·012
γ–Aminobutyric acid ..	0·014	0·046	0·054	0·066	0·014	0·026	0·034	0·042	0·056	0·016

TABLE III

Amino acids in the culture medium of F. vanisfectum *at different stages of growth*

Amino acids	Fructose-nitrate medium					Sucrose-nitrate medium				
	Days of incubation					Days of incubation				
	4	8	12	16	20	4	8	12	16	20
Glycine ..	−	−	−	+	++	−	−	−	+	++
Alanine ..	−	+	+	+	++	−	+	+	+	++
Leucines ..	+	−	−	+	++	+	−	−	+	++
Serine ..	−	+	−	+	++	−	+	−	+	++
Aspartic acid ..	+	−	+	+	++	+	−	+	+	++
Glutamic acid ..	−	+	−	+	++	−	+	−	+	++
Lysine ..	−	−	−	+	++	−	−	−	+	++

+ = present; − = absent; ++ = very prominent.

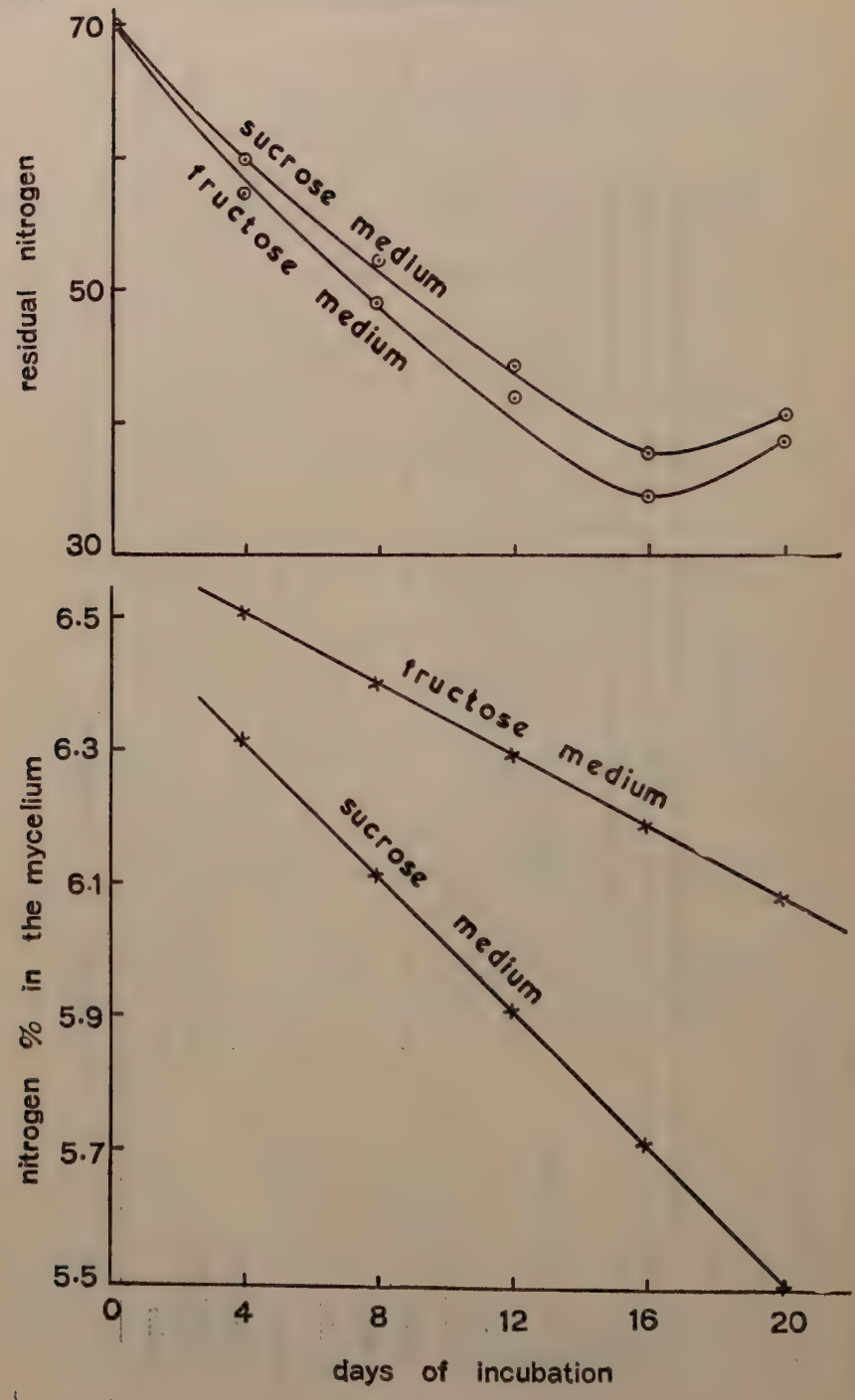
70
50
30
residual nitrogen
sucrose medium
fructose medium
6.5
6.3
6.1
5.9
5.7
5.5
nitrogen % in the mycelium
fructose medium
sucrose medium
0
4
8
12
16
20
days of incubation

FIG. 1

FIG. 1. Showing residual nitrogen (mg.) in the culture filtrate (⊙——⊙), and percentage nitrogen content in the mycelium (×——×), of *F. vasinfectum* grown in nitrate medium at different intervals of incubation.

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STUDIES IN THE FAMILY VITACEÆ

III. Floral Morphology of *Vitis latifolia* Roxb., *Vitis himalayana* Brandis and *Vitis trifolia* Linn.

By Miss G. Kashyap

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(Received for publication on October 5, 1957)

The present contribution to the morphology of *Vitis* species deals with gametophytes and endosperm development in *Vitis himalayana* and *Vitis latifolia*. Embryo development has also been described in the latter species. It also includes some further observations on *Vitis trifolia*. Previous work on the family has already been reviewed, (Kashyap, 1955). Recently, Nair and Suri (1957) have described gametophytes in *Vitis latifolia*. The floral anatomy of these species has already been described (Kashyap, 1957). Information regarding the embryogeny of the family is extremely meagre and deserves attention of the morphologists.

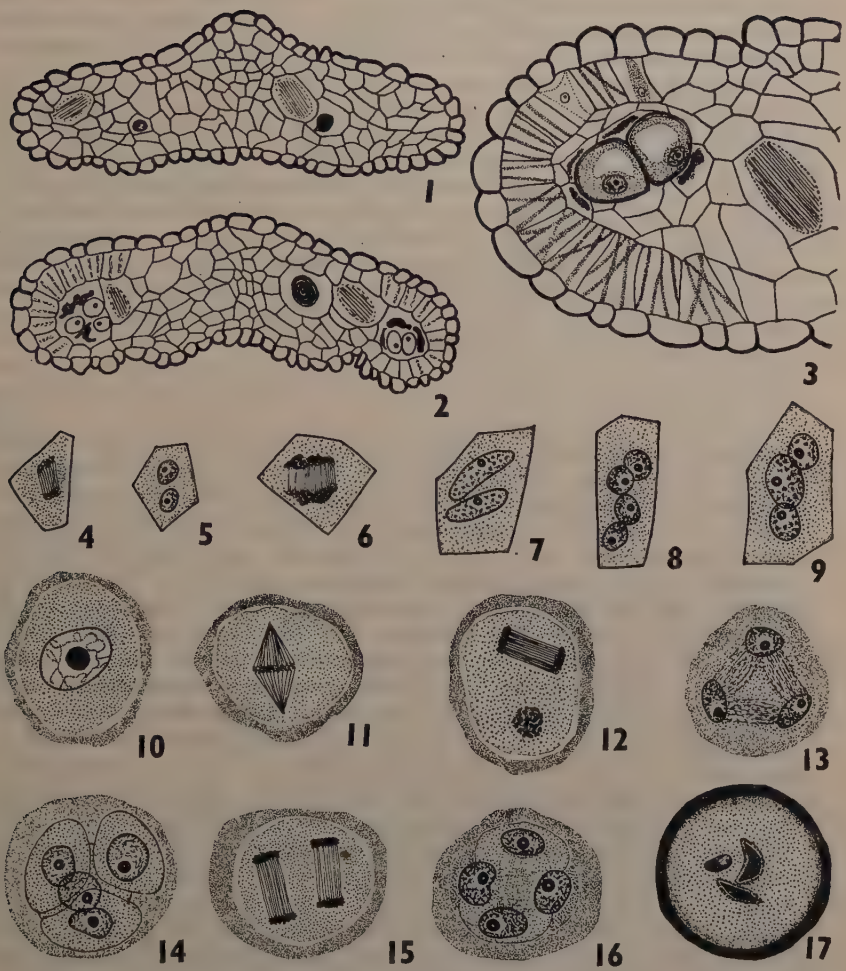
Material and Methods

Buds, open flowers, ovaries and fruits were fixed in formalin-acetic-alcohol. Usual methods of dehydration, clearing and embedding were followed through butyl alcohol series. The female gametophyte was studied in longitudinal sections of flower-buds cut at 8 to 13 microns, and the male gametophyte in transverse sections cut at 5 to 6 microns, while the post-fertilization ovaries were studied in sections cut at 12 to 20 microns thickness. Sections were stained in safranin, fast green; gention violet, erythrosin; Heidenhain's iron-alum hæmatoxyline and safranin, aniline blue. All stain combinations gave good results.

Microsporogenesis and Male Gametophyte

In *Vitis himalayana* stamens show sterilization and develop into staminodes which have large sacs containing raphides (Fig. 1). Occasionally, however, one or two showed normal development (Figs. 2, 3).

In *Vitis latifolia* the anthers have two pollen sacs. Archesporium is hypodermal in position and divides periclinally to form primary parietal layer and primary sporogenous layer. The former gives rise to wall layers, while the latter undergoes a few divisions to form the spore mother cells. Epidermis encloses endothecium, two middle layers and a glandular secretory type of tapetum. The tapetal cells become binucleate (Figs. 4, 5) while the spore mother cells are undergoing reduction division. By further divisions the tapetal cells may



FIGS. 1–17. Microsporogenesis and male gametophyte, in *Vitis himalayana* and *Vitis latifolia*. Fig. 1. *Vitis himalayana*, t.s. Staminode, ×130. Fig. 2. Same, t.s. Fertile staminode, ×130. Fig. 3. Same, magnified, ×364. Figs. 4–9. *Vitis latifolia*, divisions and fusions in the tapetal nuclei, ×777. Fig. 10. *V. latifolia*, Microspore mother cell, ×777. Fig. 11. Same, Meiosis I, ×777. Figs. 12, 13, 15 and 16, Same, Meiosis II, ×777. Fig. 14. Same, tetrad of microspores, ×777. Fig. 17. Same, three-celled pollen grain, ×777.

become multinucleate (Fig. 8). These nuclei may fuse (Fig. 9). Sometimes all the nuclei fuse to form a large polyploid nucleus. The spindles of dividing nuclei may also fuse (Fig. 6), resulting into two large oval nuclei (Fig. 7).

After reduction divisions I and II (Figs. 10–13, 15) the microspore mother cells give rise to tetrahedral, isobilateral and decussate tetrads

(Figs. 14–16). Cytokinesis takes place by furrowing (Fig. 13). The uninucleate microspores develop a central vacuole which pushes the nucleus towards the periphery where it divides into a large vegetative and a small generative cell. Later on the generative cell moves in the cytoplasm of the vegetative cell and divides into two spindle-shaped male gametes (Fig. 17). In smears long whip-like gametes were noted. Mature pollen grains are three celled, tricolpate, with a thick smooth exine. At the shedding time of pollen grains the endothecium becomes fibrous; tapetum and middle layers degenerate. Three-celled condition of the pollen grains is also known for other recently investigated species of *Vitis* (Nair and Parasuraman, 1954; Nair and Suri, 1957). In *Vitis pedata* (Mulay, Nair and Sastry, 1953) two- and three-nucleate pollen grains have been noted. Schurhoff (1926), however, stated that the pollen grains in Vitaceæ are two nucleated.

Ovule

Ovary is bicarpellary, syncarpous and bilocular with two ovules in each loculus. In one case, however, *Vitis himalayana* showed four ovules in one chamber and two in the other. In *Vitis latifolia* tri- and tetra-locular ovaries have been noted. Ovules are anatropus, bitegmic and crassinucellate. The inner integumentary primordium and the archesporium differentiate almost simultaneously (Fig. 18). At the megaspore mother cell stage the outer integument is four-layered and the inner three-layered with massive tips. By the time embryo-sac matures the outer integument becomes five to six layered and inner four-layered. The micropyle is at first formed by the inner integument, but immediately after fertilization the outer integument outgrows the inner and the micropyle is now organised by both together. Tannin is deposited in the cells of the inner epidermis of the inner integument and the outer epidermis of the outer integument. In the allied family Ce a ti ac œ an integumentary tapetum has been noted (Unpublished, Author). Well developed hypostase is present as in other *Vitis* species so far investigated (Mulay, Nair and Sastry, 1953; Adatia, Mulay and Hingorani, 1953; Nair and Suri, 1957). Nucellar beak is formed by divisions in the epidermis which starts probably at dyad stage (Fig. 21). In *Vitis pedata* a nucellar beak is reported to be absent (Mulay, Nair and Sastry, 1953). Its presence, however, is regarded as an important feature for the family (Schnarf, 1931). In *Vitis trifolia* and *Vitis latifolia* an obturator has been noted. In the former, cells from the base of the ovary elongate, become vacuolated and enter the micropyle or overarch it (Fig. 29), while in the latter it arises from the base of the ovary almost fused with the funiculus. This appears to be absent in *Vitis himalayana*.

Megasporogenesis and Female Gametophyte

Usually there is a single hypodermal archesporial cell but two archesporial cells lying side by side or one above the other are also frequent in *Vitis latifolia* (Fig. 18). More than one archesporial cells have also been reported in other species of *Vitis* (Nair and Parasuraman, 1954; Nair and Suri, 1957; Kashyap, 1955; Adatia, Mulay and

Hingorani, 1953). The archesporial cell cuts off the primary parietal cell and the primary sporogenous cell (Fig. 18). The former divides periclinally and anticlinally to form an extensive parietal tissue, the megaspore mother cell thus becomes deep-seated.

The mature mother cell has an elongated tapering form with its nucleus at the broad micropylar end (Fig. 19). A linear tetrad of four megaspores (Figs. 20–22) is formed. The chalazal functioning megaspore enlarges and becomes vacuolated. In *Vitis latifolia* two functioning megaspores were seen lying side by side (Figs. 23, 24). This has already been reported, lying one above the other in this species (Nair and Suri, 1957). The megaspore by three successive divisions (Figs. 25–27) forms the eight-nucleate Polygonum type of embryo-sac (Maheshwari, 1950). The mature embryo-sac has three antipodals arranged in a triangular or linear fashion, two polar nuclei and an egg apparatus with two beaked or hooked synergids and a central egg (Fig. 27). In some cases synergids may lack basal vacuoles so characteristic of them. In *Vitis latifolia* synergids are bigger than the egg.

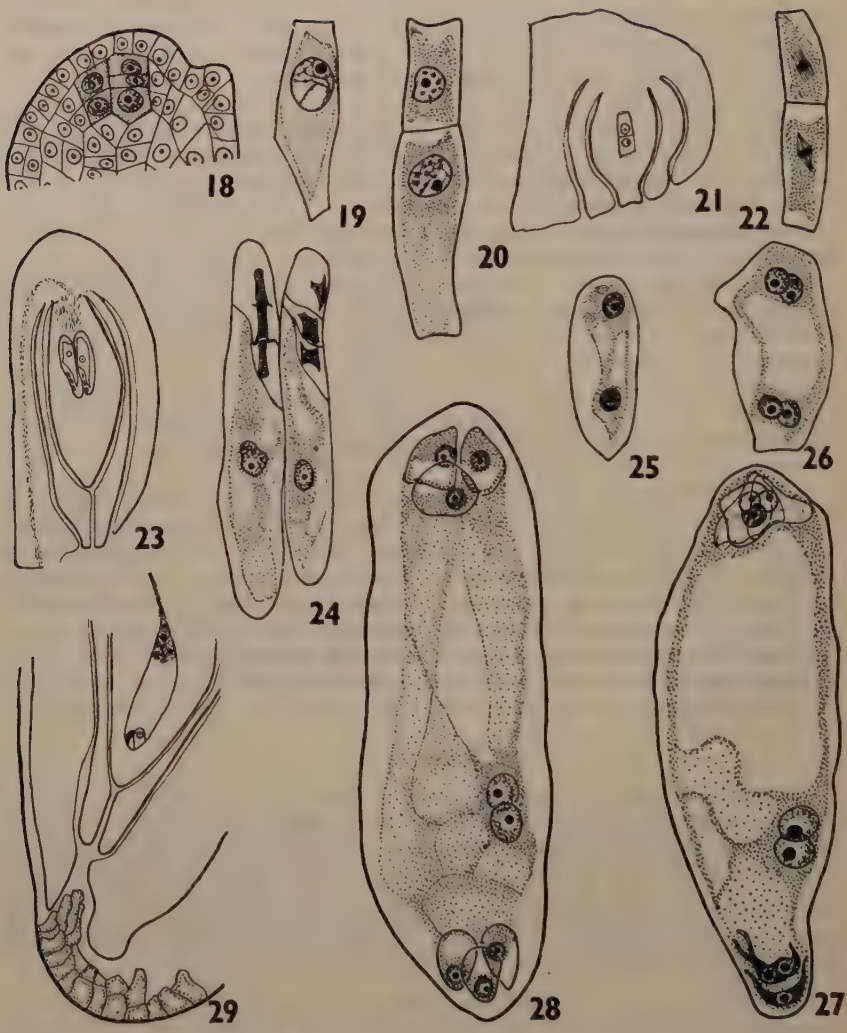
The embryo-sac in *Vitis latifolia* shows chalazal pouch enclosing the antipodals which has developed as a result of broadening up of the embryo-sac except at the chalazal end. This starts probably as early as at the two-nucleate stage of the embryo-sac. In both species antipodals are more or less crescent-shaped and degenerate quite early. In *Vitis trifolia* two antipodals have assumed synergid-like appearances and the third that of an egg as observed only in one case (Fig. 28). Such a condition has been reported sporadically in a number of cases and probably indicates that all embryo-sac nuclei are potentially alike.

Fertilization

Process of fertilization was noted in *Vitis latifolia* only. It is porogamous. While entering the ovule the pollen tube destroys one of the synergids and the other also immediately degenerates. The secondary nucleus comes to lie in the close vicinity of the egg. One male gamete fuses with the egg and the other with the secondary nucleus. In rare cases an ovule was noted in *Vitis trifolia* with persisting pollen tube. In *Vitis himalayana* the egg apparatus degenerates.

Endosperm

After fertilization the zygote undergoes a period of rest. The secondary nucleus moves to the chalazal region after receiving the male gamete. When zygote divides, endosperm has already become sixteen- to twenty-nucleate, a condition seen also in the allied family Rhamnaceæ (Arora, 1953). In *Vitis pedata*, the division of the zygote and the endosperm nucleus occurs simultaneously (Mulay, Nair and Sastry, 1953). The endosperm is of nuclear type. Early divisions are synchronous (Figs. 30, 32). Later on, however, the nuclei were found in all stages of divisions (Fig. 33). It has been noted for *Vitis himalayana* that sometimes the early divisions may not be regular and simultaneous. Out of a pair, one of the nuclei may divide earlier than the other (Fig. 31).



FIGS. 18–29. Megasporogenesis and the female gametophyte, in *Vitis himalayana*, *Vitis latifolia* and *Vitis trifolia*. Fig. 18. *V. latifolia*, Archesporium, ×529. Fig. 19. *V. himalayana*, Megaspore mother cell, ×529. Fig. 20. *V. latifolia*, Dyad cells, ×529. Fig. 21. *V. himalayana*, Ovule, showing dyad cells and nucellar beak, ×111. Fig. 22. Same, dyad dividing, ×529. Fig. 23. *V. latifolia*, Ovule, showing two functioning megaspores, ×160. Fig. 24. Same, magnified, × 529. Figs. 25 and 26. *V. himalayana*, two- and four-nucleate embryo-sacs, ×529. Fig. 27. *V. himalayana*, Mature embryo-sac, ×529. Fig. 28. *V. trifolia*, Bipolar egg apparatus, ×529. Fig. 29. *V. trifolia*, part of the ovule showing obturator, ×112.

The nuclei remain distributed throughout the cavity of the elongated embryo-sac in *Vitis latifolia*. Wall formation starts from chalazal end and is followed at the micropylar end (Figs. 34, 35); central portion

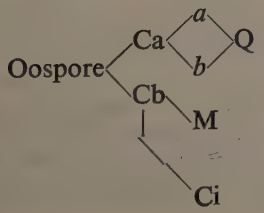
remaining free nuclear for a considerable time. The cells of the chalazal region are small and densely protoplasmic, while those at the micropylar region are large and vacuolated (Figs. 34, 35). Later on the cells at the micropylar region dissolve their walls and the nuclei lie freely in the mass of cytoplasm (Fig. 36). This probably occurs at the time when embryo is actively feeding over this tissue.

Embryogeny

Our knowledge regarding the embryogeny of the genus *Vitis* is very unsatisfactory. Most of the species of this genus usually produce ex-embryonate seeds. Nevertheless, some stages of embryo development were found in *Vitis trifolia* (Figs. 47–49). The close series, however, has been studied in *Vitis latifolia*, in which the seeds are usually fertile (Figs. 37–46).

Zygote divides transversely into a smaller terminal cell *Ca* and a large basal cell *Cb* (Figs. 37, 47). This stage is followed by an oblique vertical division in the terminal cell *Ca* to form daughter cells *a* and *b* (Fig. 39), and a transverse division in the basal cell *Cb* resulting in cells *M* and *Ci* (Fig. 38). This may result in a T-shaped proembryo. An earlier division in the basal cell may result in a linear proembryo (Fig. 38). In *Zizyphus rotundifolia* both the cells of the two-celled proembryo divide transversely resulting in a linear proembryo (Arora, 1953). The terminal tier again divides vertically at right angles to the previous plane of division. The cell *M* divides first by vertical wall to form two juxtaposed cells; *Ci* remains undivided (Figs. 40, 41). The daughter cell *a* of the terminal tier divides by the perpendicular wall to the first oblique division (Fig. 41), to cut a triangular cell *e* which is the epiphysis initial. This is followed by the oblique or meridonal division in the cell *b* of the terminal tier (Figs. 42–44). Thus there are now three tiers which may be designated as *Q*, *M* and *Ci* of which *Q* forms the cotyledonary region and the lower portion of the hypocotyl. The tier *M* forms the upper portion of the hypocotyl and the root cortex and *Ci* forms the root cap. Further divisions in the tiers result into a globular embryo (Fig. 45). The mature embryo has two elongated cotyledons (Fig. 46).

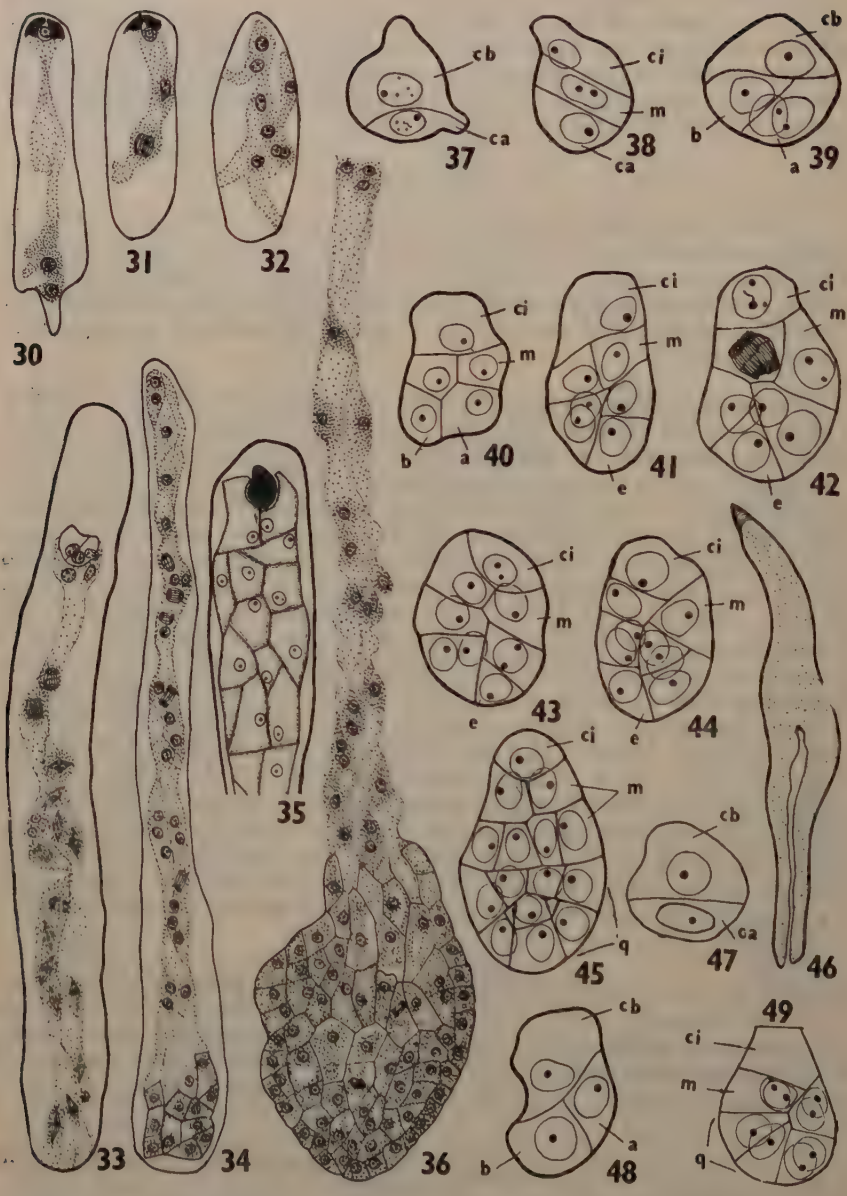
Thus the terminal and the basal cells of the proembryo contribute to the formation of the embryo. It therefore appears that the early development of the zygote follows *Geum* variation of the *Asterad* type. The following is the graphic representation showing the relation of the proembryonal cells to the parts of the mature embryo:



Cotyledonary region and lower part of the hypocotyl.

Upper part of the hypocotyl and root cortex.

Root cap.



FIGS. 30–49. Endosperm and embryo in *V. latifolia*, *V. himalayana* and *V. trifolia*. Fig. 30. *V. latifolia*, two endosperm nuclei, ×160. Fig. 31. *V. himalayana*, one endosperm nucleus divides, the other undivided, ×160. Fig. 32. Same, eight endosperm nuclei, ×160. Fig. 33. *V. latifolia*, embryo-sac two-celled; embryo and free nuclear endosperm, ×160. Fig. 34. Same, cellular endosperm at chalazal

end, ×130. Fig. 35. Same, part of the embryo-sac; embryo and cellular endosperm, ×130. Fig. 36. *V. trifolia*, Endosperm partly nuclear, ×130. Figs. 37–45. *V. latifolia*, stages in the development of the embryo, ×529. Fig. 46. *V. latifolia*, Dicot embryo, ×50. Figs. 47–49. *V. trifolia*, stages in the development of the embryo, × 529.

The Seed and the Fruit

Testa and the pericarp in *Vitis himalayana* and *Vitis latifolia* are structurally similar to that of *Vitis trifolia* (Kashyap, 1955). In *Vitis latifolia* seeds are embryonate.

Discussion

Schurhoff (1926) has stated that binucleate condition of the pollen grains is a character of the family Vitaceæ. Schnarf (1931) has also described two-nucleate pollen grains in *Vitis* species. In *Vitis trifolia* two-nucleate pollen grains have been noted (Adatia, Mulay and Hingorani, 1950; Kashyap, 1955). In *Vitis latifolia* (Nair and Suri, 1957), *Vitis pedata* (Mulay, Nair and Sastry, 1953) and *Vitis pallida* (Nair and Parasuraman, 1954), however, the pollen grains are shed at three-celled stage. It appears therefore that the prevailing condition of the pollen grains at shedding stage is three-celled.

It is interesting to note that the nucellar beak, which is so characteristic of the family (Schnarf, 1931), is reported to be absent in *Vitis pedata* (Mulay, Nair and Sastry, 1953). Micropyle is always formed by the inner integument, outer integument outgrowing the inner only after fertilization. In *Vitis pedata*, Mulay, Nair and Sastry (1953), however, report that it is formed by the inner integument and at another place they mention that it is formed by the outer one. An obturator occurs in *Vitis latifolia* and *Vitis trifolia*. It appears that it has not been observed so far in other species of *Vitis*.

Our present information about endosperm and embryo formation is very meagre. First division of the zygote and the endosperm is not simultaneous. In *Vitis pedata*, however, it is reported to be simultaneous (Mulay, Nair and Sastry, 1953).

Embryo development conforms to *Geum* variation under *Asterad* type. This differs from the *Geum* in the absence of a suspensor. Moreover, it shows close similarity with *Viola* type in which the suspensor is absent and the embryo is globular. On the basis of embryogeny it may be assumed therefore that Vitaceæ shows close affinity with Violaceæ (Maheshwari, 1950; Johansen, 1950).

Variation in the number of parts in the flower probably indicates a primitive position of the family. Possession of smooth-walled pollen grains is also regarded a primitive feature (Wodehouse, 1935). Further primitive features of the family are multicellular ovular archesporium with more than one functional cells; crassinucellate nucellus; bitegmic ovules; multi-layered integuments which are quite separate from the nucellus.

Summary

Staminodes occur in *Vitis himalayana* which may revert to fertility. Anther is bicelled and has four wall layers in *Vitis latifolia*. Glandular tapetum is multinucleate. In *Vitis himalayana* it degenerates early. Endothecium is fibrous. Pollen grains are three-celled with smooth exine. Ovules are crassinucellate, bitegmic and anatropous. Micropyle is formed by the inner integument; well formed nucellar cap is present. Usually there is a single hypodermal archesporial cell; more than one are also present. Megaspore tetrad is linear, the chalazal megaspore functions. Embryo-sac is of polygonum type. Antipodals are ephemeral. Fertilization is porogamous. First division of the zygote takes place when endosperm is about sixteen- to twenty-nucleate. Endosperm is nuclear. Cell formation starts at both ends. First division of the zygote is transverse. Embryogeny conforms to *Geum* variation of *Asterad* type. Seeds have perfect seed-coats with endosperm and embryo in *Vitis latifolia*. Fertile seeds in *Vitis trifolia* may also occur. In *Vitis himalayana* seeds are ex-embryonate.

Acknowledgement

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THE FRESH-WATER DIATOM FLORA OF THE HIREBHASGAR-DAM AREA, MYSORE STATE

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Introduction

Since there are no records available of fresh-water Diatom flora from the Hirebhasgar-dam area, the author has an interest to present the same.

The Hirebhasgar-dam is situated on the Saravati River, approximately at 14° 18′ N. and 75° 55′ E., about 20 miles by macadam road from Sagar—on Birur-Talguppa line of the Southern Railway. The place is a small village mainly inhabited by a community of maintenance-staff of the Dam.

On a Botanical excursion to the Jog-falls in 1955, this place was visited and many samples of algæ were collected, from the river-sides, dam-pavement, streams and roadside puddles, by the author. All these were preserved on the spot in 5% of commercial formalin. On return to the headquarters, then at the Rajaram College, Kolhapur, the samples were examined carefully along with many others till March 1956. The following is the account of Diatoms that occurred in the collection from the said area.

In this account the Diatoms are mainly arranged and identified according to Hustedt's (1930) monograph with the additional help of Cleve-Euler's (1951–55). The dimensions given for each specimen are those actually recorded. The descriptions and illustrations given are mostly of such specimens which are little or less known in this country.

A Systematic Enumeration of Diatoms

1. *Melosira granulata* (Ehr.) Ralfs

Van Heurck, *Treat. Diat.*, p. 444, pl. 19, fig. 621; Hustedt, *Bacil.*, p. 87, fig. 44; Cleve-Eulèr, A., *Diat. Schwed. Finn.*—I, p. 25, fig. 15 *a–b* (= *M. granulata* v. *typica* A. Cl.).

Frustules 5·5–8 μ in diameter and 12–18 μ high, cylindrical and united in chains, end cells with spines. Rows of areoles 9–10 in 10 μ.

Habitat: Dam-pavement, roadside puddles and ditches.

2. *Melosira granulata* v. *angustissima* Müll.

Hustedt, *Bacil.*, p. 88, fig. 45; Cleve-Euler, A., *Diat. Schwed. Finn.*—I, p. 25, fig. 15 *d–e*.

Frustules 3·3–4·4 μ in diameter and 24–35 μ high, narrowly cylindrical, proportion 1 : 7–8, end cells with spines and furrows. Rows of areoles 11–12 in 10 μ.

Habitat: Dam-pavement and roadside puddles. A stray form.

3. *Melosira granulata* v. *muzzanensis* Meister

Hustedt, *Bacil.*, p. 88, fig. 47; Cleve-Euler, A., *Diat. Schwed. Finn.*—I, p. 25, fig. 15 *f* [= *M. granulata* v. *muzzanensis* (Meister) Bethge].

Frustules 13–17 μ in diameter and 6–8 μ high, short cylindrical, end cells with spines and furrows. Rows of areoles 12 in 10 μ, areoles somewhat fine.

Habitat: Roadside pools, puddles and waste-water puddle from the pumping section of the dam. Found along with the species.

4. *Cyclotella stelligera* Cl. *et* Grun.
(Fig. 1)

Hustedt, *Bacil.*, p. 100, fig. 65; Cleve-Euler, A., *Diat. Schwed. Finn.*—I, p. 43, fig. 52 *a–b*.

Frustules 10–15 μ in diameter, discoid with radial striæ in the central field around a punctum, striæ 10–11 in 10 μ. Marginal striæ coarse and 12–13 in 10 μ.

Habitat: Streams and roadside puddles. Appeared to be gregarious.

5. *Cyclotella glomerata* Bachmann
(Fig. 2)

Hustedt, *Bacil.*, p. 105, fig. 81; Cleve-Euler, A., *Diat. Schwed. Finn.*—I, p. 47, fig. 59; Tiffany and Britton, *Alg. Illinois*, p. 220, pl. 58, fig. 656.

Frustules 6–10 μ in diameter, small, discoid, united in loose colonies, central field with a ring of 6 short striæ or dots. Marginal striæ 13–14 in 10 μ, fine and radial.

Habitat: Streams and roadside puddles. Found associated with the above type, also gregarious.

6. *Synedra ulna* (Nitz.) Ehr.

Hustedt, *Bacil.*, p. 151, fig. 158–9; Cleve-Euler, A., *Diat. Schwed. Finn.*—II, p. 61, fig. 382 *a* (= *S. ulna* v. *genuina* Grun.).

Valves 96–145 μ long and 6–8 μ broad, linear with constricted, produced ends. Striæ 9–10 in 10 μ.

Habitat: Widely distributed in the locality, but not abundant.

7. *Synedra ulna* v. *amphirhynchus* (Ehr.) Grun.

Hustedt, *Bacil.*, p. 154, fig. 167; Cleve-Euler, A., *Diat. Schwed. Finn.*—II, p. 62, fig. 382 *q*.

Valves 180–210 μ long and 5·6–6 μ broad, linear, bent with constricted capitate rounded ends. Striæ 9–10 in 10 μ.

Habitat: Widely distributed in the locality and common.

8. *Synedra ulna* v. *danica* (Kütz.) Grun.

Hustedt, *Bacil.*, p. 154, fig. 168; Cleve-Euler, A., *Diat. Schwed. Finn.*—II, p. 62, fig. 382 *r*.

Valves 168–205 μ long and 4·8–5 μ broad, linear-lanceolate with narrow capitate ends. Striæ 10 in 10 μ.

Habitat: Widely distributed in the locality and common.

9. *Achnanthes microcephala* Kütz.
(Figs. 3–4)

Hustedt, *Bacil.*, p. 198, fig. 273; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 40, fig. 568 *a–d* (= *A. microcephala* v. *typica* A. Cl.).

Frustules linear and bent in the middle in girdle view. Valves 13–16 μ long and 2·2 μ broad, linear-lanceolate with capitate ends. Striæ very fine, about 30 in 10 μ.

Habitat: Dam-pavement and roadside ditches. Common.

10. *Frustulia vulgaris* Thwaites
(Fig. 5)

Hustedt, *Bacil.*, p. 221, fig. 327; Lund, J. W. G., *Soil Alg.*, p. 58, fig. 2 O–P; Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 9, fig. 1329 *a–b* [= *F. vulgaris* (Thw.) Cl. v. *typica* A. Cl.]; Tiffany and Britton, *Alg. Illinois*, p. 245, p. 66, fig. 756 [= *F. vulgaris* (Thw.) De Toni]; Skvortzow, B. W., *Diat. from Khingan*, p. 42, pl. 2, fig. 12; *Diat. from Argun River*, p. 49, pl. 1, fig. 39 (= *F. vulgaris* v. *asiatica* Skv.).

Frustules found in brownish scum. Valves 44–48 μ long and 9–9·5 μ broad, linear-lanceolate with constricted, broad subrostrate ends. Raphe between thick siliceous ribs. Central area small, linear; polar areas long. Striæ 24–28 in 10 μ, fine, radial in the middle and distantly set, very finely punctate.

Habitat: Dam-pavement, streams and waste-water puddle near the pumping section of the dam. Frequently occurred in the samples.

This form appears to be a variable one and it agrees well with the type described and illustrated by Hustedt, Cleve-Euler, Lund and others. Skvortzow, however, described similar forms from Khingan and Argun River as *F. vulgaris* Thw. v. *asiatica* Skv. In the original description

of his form from Khingan, he has stated " valves lanceolate with obtuse rounded ends ", and in the case of form from Argun River " valves narrow, linear with parallel margins and subrostrate obtuse ends ", whereas the illustrations in both the cases show linear-lanceolate outline with constricted subrostrate, obtuse ends, as noted in the present form. It is, therefore, here thought that they are probably the same as *F. vulgaris* Thw. It is a new record for India.

11. *Caloneis silicula* (Ehr.) Cl.

Hustedt, *Bacil.*, p. 236, fig. 362; Cleve-Euler, A. *Diat. Schwed. Finn.*—IV, p. 98, fig. 1143 *l* [= *C. silicula* v. *undulata* (Grun.) Mayer].

Valves 28–32 μ long and 6 μ broad, linear with triundulate sides and cuneate rounded ends. Striæ 18–22 in 10 μ, fine and radial.

Habitat: Roadside ditches, pools and streams. Only a few specimens were observed.

12. *Neidium iridis* (Ehr.) Cl. v. *firmum* (Kütz.) Mayer
(Fig. 6)

Skvortzow, B. W., *Diat. from Khingan*, p. 42, pl. 2, fig. 9; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 120, fig. 1174 *h*.

Valves 53–70 μ long and 13·5 μ broad, elliptical-lanceolate with rounded cuneate ends. Raphe thick with central pores bent in opposite directions and terminal fissures bifurcated. Axial area narrow; central area somewhat obliquely elliptical and large. Striæ 18–20 in 10 μ, fine but clearly punctate, somewhat obliquely set in the middle, at length parallel and slightly convergent at the ends, crossed by a few longitudinal furrows near the sides.

Habitat: Pools in the river-bed, dam-pavement and roadside ditches. Mostly recorded as a stray specimen. It is a new record for India.

13. *Stauroneis phœnicenteron* Ehr.

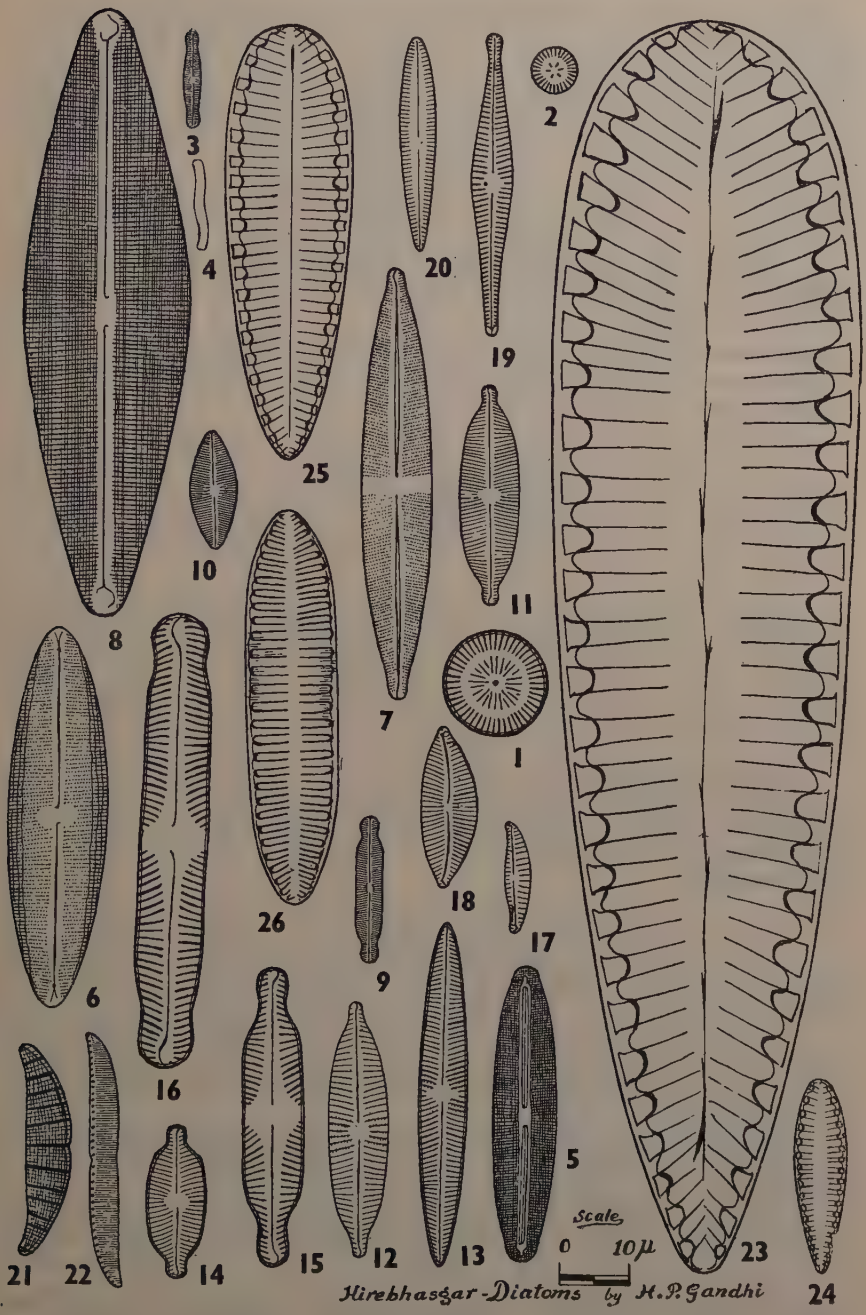
Hustedt, *Bacil.*, p. 255, fig. 404; Tiffany and Britton, *Alg. Illinois*, p. 266, pl. 71, fig. 825 [= *S. phœnicenteron* (Nitz.) Ehr.]; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 209, fig. 944 *a* (= *S. phœnicenteron* v. *genuina* A. Cl.).

Valves 80–90 μ long and 17–18 μ broad, lanceolate with slightly produced, broadly rounded ends. Striæ 15–18 in 10 μ, clearly punctate and radial.

Habitat: Pools in the river-bed, roadside ditches and puddles. Not common.

14. *Stauroneis phœnicenteron* Ehr. f. *producta* f. nov.
(Fig. 7)

Valvæ 60–120 μ longæ atque 11–22 μ latæ, anguste-lanceolatæ, apicibus constrictis atque distincte productis et rotundatis. Raphe



FIGS. 1–26

FIGS. 1–26. Fig. 1. *Cyclotella stelligera* Cl. *et.* Grun. Fig. 2. *Cyclotella glomerata* Bachmann. Figs. 3–4. *Achnanthes microcephala* Kütz. Fig. 5. *Frustulia vulgaris* Thwaites. Fig. 6. *Neidium iridis* (Ehr.) Cl. v. *firmum* (Kütz.) Mayer. Fig. 7. *Stauroneis phœnicenteron* Ehr. f. *producta* f. nov. Fig. 8. *Navicula fulva* (Nitz.) Ehr. Fig. 9. *Navicula bryophila* Boye Pet. Fig. 10. *Navicula cocconeiformis* Greg. Fig. 11. *Navicula partabgarhensis* Gandhi. Fig. 12. *Navicula rostellata* Kütz. Fig. 13. *Navicula cari* Ehr. v. *angusta* Grun. Fig. 14. *Navicula dicephala* (Ehr.) W. Sm. v. *sphærophora* A. Cl. Fig. 15. *Pinnularia interrupta* W. Sm. Fig. 16. *Pinnularia stauroptera* (Rabh.) Cl. v. *subparallela* A. Cl. Fig. 17. *Cymbella kerkevarensis* A. Cl. Fig. 18. *Cymbella ventricosa* Kütz. v. *minuta* (Hilse) Van Heurck. Fig. 19. *Gomphonema subtile* Ehr. Fig. 20. *Gomphonema vastum* Hust. v. *elongata* Skv. Fig. 21. *Rhopalodia musculus* (Kütz.) O.Müll. Fig. 22. *Nitzschia ignorta* Krasske. Fig. 23. *Surirella tenera* Greg. v. *nervosa* A. S. Fig. 24. *Surirella subsalsa* W. Sm. Fig. 25. *Surirella subsalsa* W. Sm. f. *major* f. nov. Fig. 26. *Surirella asymmetrica* Østrup v. *serpentina* A. Cl.

crassa, poris centralibus distinctis; fissuris terminalibus curvatis. Area axialis angusta; area centralis linearis-staurodea. Striæ 22–23 in 10 μ, radiales, tenues sed distincte punctatæ.

Valves 60–120 μ long and 11–22 μ broad, narrowly lanceolate with constricted, produced rounded ends. Raphe thick with central pores distinct, and curved terminal fissures. Axial area narrow; central area a linear stauros. Striæ 22–23 in 10 μ, radial, fine but distinctly punctate.

Habitat: Dam-pavement, roadside pools and ditches. Frequently appearing in the samples. It is also recorded from Rankala tank, Kolhapur, hilly streams at Radhanagari [in my paper on Radhanagari Diatoms (1957), I have treated this specimen as a type proper, which I now consider to be a new form]. Fairly common in the locality.

This form agrees with *S. phœnicenteron* Ehr., as described by Hustedt and others (Hust., p. 255, fig. 404). However, it differs from it in having constricted, distinctly produced rounded ends and comparatively finer striæ which are closely set than in the type. It is, therefore, regarded as a new form.

15. *Navicula cuspidata* Kütz.

Hustedt, *Bacil.*, p. 268, fig. 433; Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 17, fig. 1353 *a–c* (= *N. cuspidata* v. *genuina* A. Cl.).

Valves 110–130 μ long and 27–30 μ broad, rhombic-lanceolate with slightly produced rounded ends. Longitudinal striæ 18–20 in 10 μ and transverse striæ 16 in 10 μ, somewhat coarse and perpendicular to the middle line.

Habitat: Widely distributed in the locality, but not abundant. Some forms with craticular plates were also recorded.

16. *Navicula fulva* (Nitz.) Ehr.
(Fig. 8)

Donkin, A. S., *Brit. Fresh-water Diat.*, 41, pl. 6, fig. 9; Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 17, fig. 1352.

Valves 85–95 μ long and 22–23 μ broad, rhombic-lanceolate with broad or obtusely rounded ends, ends not at all produced. Raphe thin and straight with inconspicuously hook-like central pores and terminal fissures shortly curved. Axial area very narrow; central area scarcely formed. Transverse striæ 14–15 in 10 μ, scarcely radial and indistinctly punctate or the longitudinal striæ indistinct.

Habitat: Dam-pavement and roadside pools. It occurred only in a few samples.

Cleve-Euler regards Hustedt's form *N. cuspidata* Kütz. as *N. fulva*, but I do not consider it to be so with the material at my disposal, since Hustedt's form has rather produced and acutely rounded ends, whereas in *N. fulva*, they are not at all produced nor acutely rounded. Moreover, the longitudinal striæ in the former are not so fine as to become indistinct as observed in *N. fulva*. I, therefore, prefer to keep these forms separate and as distinct species. It is a new record for India.

17. *Navicula pupula* Kütz.

Hustedt, *Bacil.*, p. 281, fig. 467 *a*; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 186, fig. 890 *a–c* (= *N. pupula* v. *genuina* Grun.).

Valves 25–28 μ long and 7·5 μ broad, lanceolate with somewhat constricted, broadly rounded ends. Striæ 22–24 in 10 μ, radial and curved.

Habitat: Roadside pools, puddles and ditches. Common in the samples collected.

18. *Navicula pupula* v. *rectangularis* (Greg.) Grun.

Hustedt, *Bacil.*, p. 281, fig. 467 *b*; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 187, fig. 890 *d–f*.

Valves 25–30 μ long and 7–7·5 μ broad, linear with broadly rounded ends. Striæ 24–26 in 10 μ, radial and curved.

Habitat: Roadside pools, puddles and dam-pavement. Fairly common with the species.

19. *Navicula pupula* v. *capitata* Hust.

Hustedt, *Bacil.*, p. 281, fig. 467 *c*; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 187, fig. 890 *h*.

Valves 22–28 μ long and 7·6 μ broad, linear-lanceolate with constricted broadly capitate rounded ends. Striæ 22–26 in 10 μ, radial, curved and fine.

Habitat: Roadside pools, puddles and dam-pavement. Less frequent in the samples.

20. *Navicula bryophila* Boye Pet.
(Fig. 9)

Petersen, J. B., *Aërial Alg. Iceland*, p. 388, fig. 13; *Alg. Pamir Exped.* 1898–99, p. 38, fig. 6; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 175, fig. 865 *e–f* (= *N. bryophila* v. *lapponica* Hust.).

Valves 18–22 μ long and 4–4·5 μ broad, delicate, linear with constricted, broadly capitate or subcapitate rounded ends. Raphe thin and straight. Axial area very narrow; central area narrowly elliptical. Striæ 24–30 in 10 μ, radial throughout, end striæ rather finer than the middle ones, closely set and almost indistinct.

Habitat: Dam-pavement and waste-water puddle near the pumping section of the dam. Only a few specimens were observed in the collection.

This form agrees well with the type reillustrated by Peterson in "*Alg. Pamir Exped.*—1898–99". It also agree with Cleve-Euler's *N. bryophila* v. *lapponica* Hust., in the outline, capitate ends and coarser striations in the middle region. However, Cleve-Euler has described and illustrated the striations at the ends to be convergent which are not so recorded in the present form. Boye Petersen also has not indicated them to be convergent at the poles both in the description and illustrations. This form makes a new record for India.

21. *Navicula cocconeiformis* Greg.
(Fig. 10)

Hustedt, *Bacil.*, p. 290, fig. 493; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 196, fig. 916.

Valves 14–21 μ long and 6·6–7·7 μ broad, broadly rhombic-lanceolate with inconspicuously constricted, obtusely rounded ends. Striæ 26–28 in 10 μ, radial, finely punctate, short and long alternating in the middle.

Habitat: Dam-pavement, roadside pools and waste-water puddle near the pumping section of the dam. Fairly common in the locality.

22. *Navicula cryptocephala* Kütz.

Hustedt, *Bacil.*, p. 295, fig. 496; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 154, fig. 813 *a–e* (= *N. cryptocephala* v. *genuina* A. Cl.).

Valves 27–30 μ long and 5–5·4 μ broad, lanceolate with constricted, produced, feebly capitate ends. Striæ 14–17 in 10 μ.

Habitat: Widely distributed in the locality and common.

23. *Navicula partabgarhensis* Gandhi
(Fig. 11)

Gandhi, H. P., *Fresh-water Diat. Partabgarh*, p. 320, fig. 20.

Valves 30–40 μ long and 7·8–8·5 μ broad, linear-elliptical with constricted capitate ends. Raphe thin and straight. Axial area narrow; central area fairly large, roundish. Striæ 18–20 in 10 μ, lineate, radial in the middle and convergent at the ends, 1–2 middle striæ short but not alternating with long ones.

Habitat: Roadside pools, puddles and ditches. Fairly common.

This form on comparison with the original type agrees well in all the details, except that it is only slightly broader.

24. *Navicula rostellata* Kütz.
(Fig. 12)

Hustedt, *Bacil.*, p. 297, fig. 502; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 158, fig. 818 *d–e* (= *N. rostellata* v. *minor* V. H.).

Valves 33–40 μ long and 8–9 μ broad, linear-lanceolate with somewhat abruptly constricted, produced ends. Striæ 10–14 in 10 μ, lineate, radial in the middle and convergent at the ends.

Habitat: Roadside pools, puddles and ditches. Fairly well distributed.

This form agrees well with the type described by Hustedt and others, except that comparatively smaller forms were also recorded with somewhat faint striations.

25. *Navicula cari* Ehr. v. *angusta* Grun.
(Fig. 13)

Hustedt, *Bacil.*, 299; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 153, fig. 810 *b*.

Valves 48–56 μ long and 6–8 μ broad, narrowly lanceolate with unconstricted rounded ends. Raphe thin and straight with curved terminal fissures. Axial area narrow, linear; central area large, quadrate. Striæ 12–14 in 10 μ, indistinctly lineate, radial in the middle and convergent at the ends, middle striæ very short.

Habitat: Widely spread in the locality, sometimes gregarious. Very common. Also recorded from Lonavala, Jog-falls, Sagar and Radhanagari. It appears that this diatom prefers hilly places. It is a new record for India.

26. *Navicula radiosa* Kütz. v. *tenella* (Bréb.) Grun.

Van Heurck, *Treat. Diat.*, p. 180, pl. 3, fig. 114; Hustedt, *Bacil.*, p. 299; Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 156, fig. 816 *m–n* [= *N. radiosa* v. *tenella* (Bréb.) V. H.].

Valves 48–50 μ long and 7 μ broad, narrowly lanceolate with acute ends. Striæ 14–18 in 10 μ, radial in the middle and convergent at the ends.

Habitat: Roadside ditches and puddles. Noted as a stray form.

27. *Navicula dicephala* (Ehr.) W. Sm. v. *sphærophora* A. Cl. (Fig. 14)

Cleve-Euler, A., *Diat. Schwed. Finn.*—III, p. 143, fig. 792 *g–h*.

Valves 22–30 μ long and 7–8 μ broad, linear or linear-elliptical with constricted, capitate rounded ends. Raphe thin and straight. Axial area narrow, linear; central area fairly large, roundish. Striæ 13–16 in 10 μ, radial throughout and curved, indistinctly punctate and somewhat closely set at the ends.

Habitat: Widely spread in the locality and sometimes gregarious. Common. It is also recorded from the Jog-falls and Sagar. It makes a new record for India.

This form agrees well with the type described and illustrated by Cleve-Euler, except that some smaller and other larger forms were also recorded from this area.

*28. *Pinnularia acrosphæria* Bréb.

Hustedt, *Bacil.*, p. 330, fig. 610; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 25, fig. 1022 *a–b* [= *P. acrosphæria* (Bréb.) W. Sm. v. *genuina* Cl.]; Donkin, A. S., *Brit. Fresh-water Diat.*, p. 72, pl. 12, fig. 2 (=*Navicula acrosphæria* Bréb.).

Valves 70–85 μ long and 10–11 μ broad, slightly swollen in the middle and at the broadly rounded ends. Striæ 11–12 in 10 μ.

Habitat: Roadside pools, puddles and ditches. In one sample it was found to be gregarious. Frequent.

29. *Pinnularia acrosphæria* f. *undulata* Cl.

Hustedt, *Bacil.*, p. 330; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 25, fig. 1022 *c*.

Valves 56–60 μ long and 10·5 μ broad, linear with undulate sides and broadly rounded ends. Striæ 10–12 in 10 μ.

Habitat: road-side pools. It occurred as a stray form.

30. *Pinnularia acrosphæria* v. *minor* Cl.

Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 25, fig. 1022 *d*.

Valves 37–40 μ long and 8·5 μ broad, linear, small with very slightly swollen middle and the end portions. Striæ 12–13 in 10 μ.

Habitat: Fairly well distributed in the locality. Frequent.

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* Genus *Pinnularia* is arranged according to Cleve-Euler's monograph, since a very large number of forms are described, rearranged and some sections modified and a few newly added in it.

31. *Pinnularia interrupta* W. Sm.
(Fig. 15)

Hustedt, *Bacil.*, p. 317, fig. 573 *b*; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 63, fig. 1088 *k–n* [= *P. biceps* Greg. v. *minor* (Boye Pet.) A. Cl.].

Valves 42–50 μ long and 8·5–9 μ broad, linear with narrowed, constricted, produced subcapitate rounded ends. Raphe thin and straight. Axial area narrow, sublinear; central area very large, rhomboid and reaching the sides. Striæ 10–12 in 10 μ, coarse, radial in the middle and convergent at the ends, striæ in the middle part progressively becoming shorter till they disappear.

Habitat: Wide-spread in the region but not abundant.

In the collection from the Hirebhasgar area, all the specimens showed the central area very large, reaching the sides and the middle radial striæ progressively becoming shorter until disappearing in the centre. In this regard, therefore, it does not agree with *P. interrupta* W. Sm. (Hustedt, *op. cit.*, p. 317, fig. 573 *a*) which is treated as *P. biceps* Greg. v. *typica* A. Cl., by Cleve-Euler (Cleve-Euler, *loc. cit.*, p. 62, fig. 1088 *a, c–d*). On the other hand, it fairly resembles *P. interrupta* as illustrated by Hustedt (fig. 573 *b*) which according to Cleve-Euler is *P. biceps* v. *minor* (Boye Pet.) A. Cl. (Cleve-Euler's fig. 1088 *l*) as also Boye Petersen's form *P. interrupta* f. *minor* Boye Pet. (Boye Petersen, *Aërial Alg. Iceland*, p. 405, fig. 25). The present form shows the outline, central area and middle striæ like that in *P. interrupta* f. *minor* Boye Pet., but differs in having much larger dimensions and somewhat coarser striæ fewer in number. In the opinion of the present author, it is probable that *P. interrupta* (Hustedt's fig. 573 *b*) and *P. biceps* Greg. v. *minor* (Boye Pet.) A. Cl. (Cleve-Euler's fig. 1088 *k–n*) are the same as *P. interrupta* W. Sm., with some minor variations. Whereas, Boye Petersen's form may be treated as *P. interrupta* f. *minor* Boye Pet., as also Cleve-Euler's similar smaller forms *P. biceps* v. *minor*, with it.

32. *Pinnularia stauroptera* (Rabh.) Cl. v. *subparallela* A. Cl.
(Fig. 16)

Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 68, fig. 1091 *n*.

Valves 60–70 μ long and 9–10 μ broad, linear, inconspicuously triundulate with ends constricted and broadly capitate-rounded. Raphe thin, slightly wavy with unilaterally bent central pores and curved terminal fissures. Axial area narrow, linear; central area large, rhomboid and reaching the sides. Striæ 9–11 in 10 μ, coarse, radial in the middle and convergent at the ends.

Habitat: Dam-pavement and a roadside ditch. Rather a stray form. This form is a new record for India.

33. *Cymbella kerkevarensis* A. Cl.
(Fig. 17)

Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 146, fig. 1215.

Valves 24–28 μ long and 8–8·5 μ broad, asymmetrical with dorsal side highly convex, ventral side moderately convex and the ends feebly constricted, rounded and produced. Raphe thin, almost central with ventrally bent central pores. Axial area very narrow; central area small. Striæ 13–14 in 10 μ, throughout radial and punctate.

Habitat: Dam-pavement, roadside pools and puddles. Very common in the locality. This diatom was also collected from the Jog-falls and Sagar. It is a new record for India.

34. *Cymbella turgida* (Greg.) Cl.

Hustedt, *Bacil.*, p. 358, fig. 660; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 123, fig. 1176 *a–d*.

Valves 50–55 μ long and 12–13 μ broad, dorsal side convex, ventral side almost straight with a median gibbosity, ends acute. Striæ 7–11 in 10 μ, coarsely lineate.

Habitat: road-side pools and ditches. A stray form.

35. *Cymbella ventricosa* Kütz.

Hustedt, *Bacil.*, p. 359, fig. 661; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 124, fig. 1177 *a–c* (= *C. ventricosa* v. *genuina* Mayer).

Valves 37–39 μ long and 11 μ broad, with slightly convex ventral side and highly convex dorsal side with acutely rounded ends. Striæ 10–11 in the middle and 13–16 in 10 μ at the ends, finely punctate.

Habitat: Roadside ditches and pools. A stray form.

36. *Cymbella ventricosa* Kütz. v. *minuta* (Hilse) V. H.
(Fig. 18)

Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 125, fig. 1177 *g–i*.

Valves 15–17 μ long and 4·4–5 μ broad, small, with dorsal side convex and ventral side straight with a broad median inflation, ends rounded and somewhat ventrally bent. Raphe thin and straight. Axial area narrow; central area small. Striæ 13–14 in the middle and upto 16 in 10 μ at the ends, radial in the middle.

Habitat: fairly well distributed in the locality. It was also collected from the Jog-falls and Sagar where, in some collections, it appeared to be gregarious. It makes a new record for India.

37. *Gomphonema sphærophorum* Ehr.

Hustedt, *Bacil.*, p. 372, fig. 695; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 176, fig. 1267.

Valves 35–37 μ long and 7–8 μ broad, clavate with strongly constricted capitate apex and narrowed, produced capitate base. Striæ 12–16 in 10 μ, radial and punctate.

Habitat: Roadside pools, puddles and ditches. Mostly as a stray specimen.

38. *Gomphonema parvulum* (Kütz.) Grun.

Hustedt, *Bacil.*, p. 372, fig. 713 *a*; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 177, fig. 1269 *a–c* [= *G. parvulum* (Kütz.) V. H. v. *genuinum* Mayer].

Valves 20–25 μ long and 6·5 μ broad, lanceolate-clavate with shortly constricted produced ends. Striæ 13–16 in 10 μ, radial and faintly punctate.

Habitat: Fairly well distributed in the locality.

39. *Gomphonema parvulum* v. *subelliptica* Cl.

Hustedt, *Bacil.*, p. 373, fig. 713 *b*; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 178, fig. 1269 *h–j* (= *G. parvulum* v. *subellipticum* Cl.).

Valves 14–18 μ long and 6·6 μ broad, elliptical-clavate with scarcely constricted produced ends. Striæ 13–16 in 10 μ, radial.

Habitat: Dam-pavement, roadside pools and ditches. Sparingly seen in the collection.

40. *Gomphonema subtile* Ehr.
(Fig. 19)

Hustedt, *Bacil.*, p. 376, fig. 709; Cleve-Euler, A., *Diat. Schwed. Finn.*—IV, p. 177, fig. 1268 *c* (= *G. subtile* v. *rotundatum* A. Cl.).

Valves 30–46 μ long and 5–6 μ broad, narrowly lanceolate-clavate, delicate, with slightly capitate broadly rounded apex and gradually attenuated produced rounded base. Raphe thin and straight. Axial area narrow; central area unilateral with an isolated stigma. Striæ 12–14 in 10 μ, indistinctly punctate.

Habitat: Dam-pavement, waste-water puddle near the pumpin section of the dam. A stray form. It is a new record for India.

41. *Gomphonema vastum* Hust. v. *elongata* Skv.
(Fig. 20)

Skvortzow, B. W., *Diat. from Kizaki Lake*, p. 51, pl. 13, figs. 33, 40.

Valves 28–35 μ long and 4·5–5·5 μ broad, clavate-lanceolate with rounded apex and attenuated base. Raphe thin and straight. Axial area broadly lanceolate, almost $\frac{1}{2}$ the breadth of the valve; central area undefined, but with an isolated stigma on one side. Striæ 14–18 in 10 μ, slightly radial, marginal and fine.

Habitat: Well distributed in the locality and common. It is also recorded from the Jog-falls and Sagar, occasionally gregarious. It is a new record for India. So far known only from Nippon area.

42. *Rhopalodia musculus* (Kütz.) O. Müll.
(Fig. 21)

Hustedt, *Bacil.*, p. 392, fig. 745; Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 43, fig. 1415 *k–l* [= *R. gibberula* (Ehr.? Kütz) O. Müll. v. *constricta* (W. Sm.) A. Cl.].

Frustules solitary, elliptical with broadly rounded, sometimes constricted at the ends in girdle view. Valves 28–32 μ long and 6–6·6 μ broad with almost straight ventral side convex to semi-circular dorsal side with ventrally bent, acutely rounded ends, dorsal part in the middle somewhat notched. Costæ 3–5 in 10 μ, alternating with 5–8 rows of alveoli; rows of alveoli 14–15 in 10 μ, radially arranged and fine.

Habitat: Dam-pavement and a roadside pool. A stray form. It is a new record for India.

43. *Nitzschia ignorta* Krasske
(Fig. 22)

Hustedt, *Bacil.*, p. 422, fig. 819; Lund, J. W. G., *Soil. Alg.*, p. 97, figs. 14 J–K, 15 A–G; Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 78, fig. 1478 *c* [= *N. filiformis* (W. Sm.) Hust. v. *ignorta* (Krasske) A. Cl.].

Valves 33–45 μ long and 4–4·5 μ broad, linear sigmoid with obliquely rounded-wedge-shaped ends. Keel excentric, sigmoid with a median constriction and keel punctæ small, rounded, 10–11 in 10 μ. Striæ about 35 in 10 μ, very fine and almost indistinct.

Habitat: Well distributed in the locality and fairly common. This diatom is also recorded from Kolhapur, Jog-falls and Mugad, but as a stray specimen. It makes a new record for India.

44. *Surirella tenera* Greg.

Hustedt, *Bacil.*, p. 438, fig. 853; Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 104, fig. 1525 *a–b* (= *S. tenera* v. *genuina* A. Cl.).

Valves 128–140 μ long and 35–38 μ broad, linear-ovate to long-ovate with broadly rounded apex and cuneate rounded base. Costæ 16–22 in 100 μ, radial at the ends.

Habitat: Widely spread in the locality, but not abundant. It is also collected from the Jog-falls (here in some places found to be gregarious), Sagar, Panhalgarh, Bombay and other places. Common.

45. *Surirella tenera* v. *nervosa* A. Schmidt.
(Fig. 23)

Hustedt, *Bacil.*, p. 439, fig. 854; Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 104, fig. 1525 *c–e*.

Valves 71–165 μ long and 16·5–44 μ broad, heteropolar, linear-ovate to long-ovate with broadly rounded apex and cuneate base. Middle line irregualrly spinuous beset with strong terminal spines. Costæ 18–22 in 100 μ, radial at the ends.

Habitat: Widely distributed in the locality. Also collected from the Jog-falls and Sagar. Very common.

46. *Surirella subsalsa* W. Sm.
(Fig. 24)

Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 105, fig. 1526 *a–d*, f (= *S. subsalsa* v. *smithii* A. Cl.).

Valves 27–35 μ long and 6·6–9·5 μ broad, heteropolar, ovate or ovate-lanceolate with acutely rounded base. Axial field narrow, linear to lanceolate, Costæ 35–40 in 100 μ.

Habitat: Dam-pavement, roadside ditches, pools and puddles. Fairly well seen in the collection.

47. *Surirella subsalsa* f. *major* f. nov.
(Fig. 25)

Frustula cuneata in aspectu zonali. Valvæ 60–65 μ longæ atque 16–17 μ latæ, heteropolares, ovatæ cuneatæ. Area axialis angusta-lanceolata cum linea media. Rugæ marginales distincte, undulatæ cum projectionibus indistinctis. Costæ 35–40 in 100 μ, striæ indistincte.

Frustules cuneate in girdle view. Valves 60–65 μ long and 16–17 μ broad, heteropolar and ovate-cuneate. Axial area narrowly lanceolate with a median line. Marginal folds distinct and undulated but with indistinct projections. Costæ 35–40 in 100 μ, striæ indistinct.

Habitat: Dam-pavement and roadside pools. A stray form.

This diatom differs from the above named type in being larger n dimensions and in having ovate-cuneate outline. It is, therefore, entatively regarded as a new form.

48. *Surirella asymmetrica* Østrup v. *serpentina* A. Cl.
(Fig. 26)

Cleve-Euler, A., *Diat. Schwed. Finn.*—V, p. 114, fig. 1545 *b–f*.

Valves 55–58 μ long and 13·5–14 μ broad, scarcely heteropolar, linear or sublinear with cuneate or subcuneate rounded ends. Axial area very narrow, linear, median line not seen. Marginal folds feebly developed. Costæ 40–45 in 100 μ, striæ indistinct.

Habitat: Dam-pavement, roadside puddle and a pool in the river-bed. A stray form.

Summary

For the first time the Diatoms from Hirebhasgar-dam area has been described in these pages and illustrations given only of those forms which are little or less known in this country.

In all forty-eight Diatoms are recorded from the said area of which two are considered to be new forms and fourteen new records for this country.

Acknowledgement

The author takes this opportunity to express his grateful thanks to Drs. J. W. G. Lund, J. B. Peterson, F. Hustedt, Åke Berg and Mr. Voigt for rendering help with the literature.

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STUDIES IN LAURACEÆ

II. Embryology of *Cinnamomum* and *Litsea*

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(Received for publication on December 26, 1957)

In the first paper of this series the author (Sastri, 1952) described the floral anatomy of *Cinnamomum iners* and *Cassytha filiformis*. The present paper is on the embryology of *Cinnamomum iners* Reinw., *C. zeylanicum* Linn. and *Litsea sebifera* Pers.

The earliest embryological work in the family Lauraceæ is by Mirande (1905) who made some observations on the structure of the ovule, fruit and seed of *Cassytha filiformis*. The results of his study will be discussed in the next paper of this series, which deals with a detailed study of the life history of *Cassytha filiformis* and some other species of this genus. In their study on *Cinnamomum seiboldi* Tackholm and Soderberg (1917) recorded successive division of pollen mother cells, presence of numerous megaspore mother cells in the ovule and Polygonum type of embryo-sac development. Giuliani (1928) found Polygonum type of embryo-sac development in *Cinnamomum camphora*. Coy (1928) gave the first detailed and complete account of the structure and development of pollen, ovule, embryo-sac, endosperm, embryo and seed in this family based on his study on *Sassafras verifolium* in which he reported: periplasmodial anther tapetum, nuclear endosperm, presence of " transfusion tissue " in the seed-coat and development of a stony layer in the fruit wall. Bambacioni-Mezzetti (1935) studied the development of the male and female gametophytes and endosperm in *Laurus nobilis*, the salient feature in his study being the increase in the number of antipodals up to six. Tongiorgi (1935) studied microsporogenesis in *Cinnamomum camphora*. Mezzetti-Bambacioni (1941) studied the development of male and female gametophytes in *Umbellularia californica* and male gametophyte in *Laurus canariensis*. Battaglia (1947) in the course of his cytological studies on *Laurus nobilis* reported the occurrence of linear, isobilateral and T-shaped pollen tetrads. Schroeder (1952) in his study of the embryology of *Persea americana* reported the origin of the anther tapetum from the sporogenous tissue and a single archesporial cell in the ovule. The present author published some preliminary observations (Sastri, 1956 and 1957) on the embryology of *Cassytha filiformis* in which he reported the formation of numerous embryo-sacs per ovule and their haustorial elongation.

The present work was undertaken, in view of the unsatisfactory and incomplete state of our knowledge of the course of embryo deve-

lopment in the genus *Cinnamomum* and lack of information on the embryology of the genus *Litsea*.

Materials and Methods

Material of *Cinnamomum iners* was fixed in formalin-acetic-alcohol from plants growing in the Indian Botanic Garden, Calcutta, and this was supplemented by material sent by Mr. R. S. Rao from the same place. Material of *Litsea sebifera* fixed in formalin-acetic-alcohol was also sent by Mr. R. S. Rao from Calcutta. Fixed material of *Cinnamomum zeylanicum* was sent by Mr. B. S. M. Dutt from Pithapuram. Customary methods of dehydration, infiltration and embedding were employed and sections were cut from 5–12 microns in thickness and stained in Delafield's hæmatoxylin. A combination of safranin and fast green was also used for some slides.

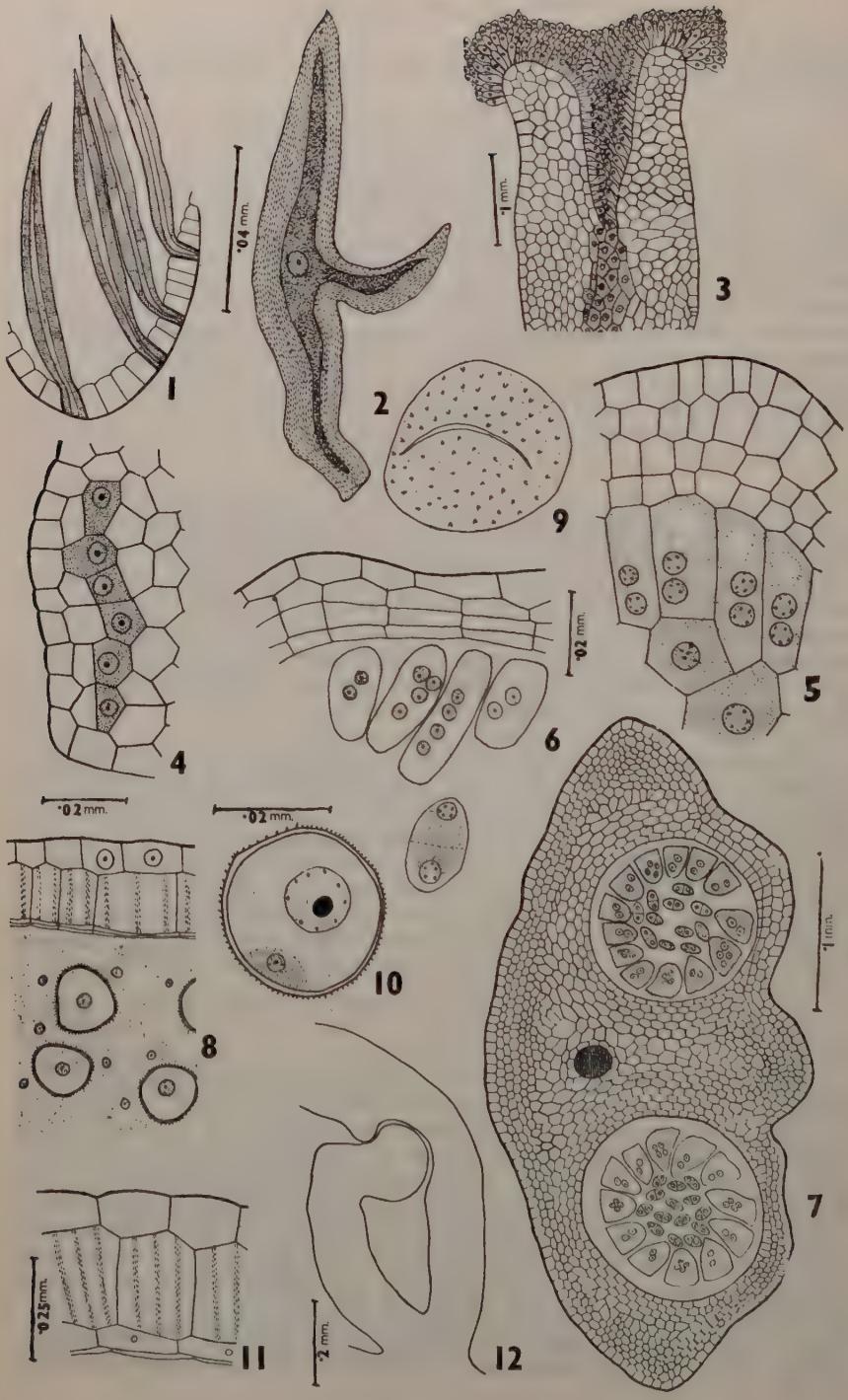
Observations

The Flower.—The floral structure of *Cinnamomum zeylanicum* is similar to *C. iners* (Sastri, 1952). The flower of *Litsea sebifera* is unisexual and the male flower has a pistillode (Fig. 12). But for this, the floral structure of this species is similar to *Cinnamomum*. The style in all the species is solid throughout except for a narrow stylar canal at the base and has a transmitting tissue of two or three layers of cells, rich in cytoplasm and starch grains. The stigma has a characteristic tuft of unicellular hairs (Fig. 3) whose structure and distribution are uniform in all species studied.

Unicellular, thick-walled hairs or trichomes occur throughout the surface of floral parts, the degree of their abundance varying from species to species. They are more profuse in *C. zeylanicum* and *Litsea sebifera* than in *C. iners*. The trichome arises from the epidermal cell as a papillate projection elongating considerably during further development. Its wall becomes thickened and finely lamellated. The lumen of the trichome becomes occluded and is filled with darkly staining, densely packed contents. The trichomes are usually unbranched (Fig. 1); rarely they give rise to a short lateral branch (Fig. 2).

In all species ethereal oil cells are scattered in the different parts of the flower.

Microsporogenesis.—A row of about five or six hypodermal archesporial cells differentiates in each lobe of the young anther and they undergo a periclinal division (Fig. 4) giving rise to an outer row of primary parietal cells and an inner of sporogenous cells. The primary parietal cells by further periclinal divisions form an anther wall (Fig. 5) of four layers (excluding the epidermis) of which the innermost forms a tapetum whose cells become two-nucleate (Fig. 5) as the microspore mother cells are about to divide meiotically. In *Cinnamomum zeylanicum* some tapetal cells become four-nucleate (Fig. 6). The tapetal cells become radially elongated and free from one another (Figs. 6 and 7) at the end of the first meiotic division in microspore mother cells. By the time the uninucleate microspores are formed



TEXT-FIGS. 1–12

TEXT-FIGS. 1–12. Fig. 1. L.s. unicellular trichomes from the epidermis of a tepal in *Cinnamomum zeylanicum*. Fig. 2. L.s. branching trichome in *Cinnamomum iners*. Fig. 3. L.s. apical region of style showing stigmatic hairs and transmitting tissue in *C. iners*. Fig. 4. L.s. young anther lobe showing periclinal division of primary archesporium in *C. iners*. Fig. 5. T.s. portion of anther lobe showing binucleate tapetum and pollen mother cells in *C. iners*. Fig. 6. L.s. portion of anther lobe showing 4-nucleate tapetal cells and first division of pollen mother cell in *C. zeylanicum*. Fig. 7. T.s. young anther of *C. zeylanicum*. Fig. 8. L.s. portion of anther lobe showing fibrous endothecium, periplasmodial tapetum and uninucleate pollen grains in *C. zeylanicum*. Fig. 9. Surface view of mature pollen grain of *Litsea sebifera*. Fig. 10. Mature pollen grain of *C. zeylanicum* in sectional view. Fig. 11. L.s. portion of mature anther wall showing fibrous endothecium in *Litsea sebifera*. Fig. 12. L.s. pistillode in male flower of *Litsea sebifera*.

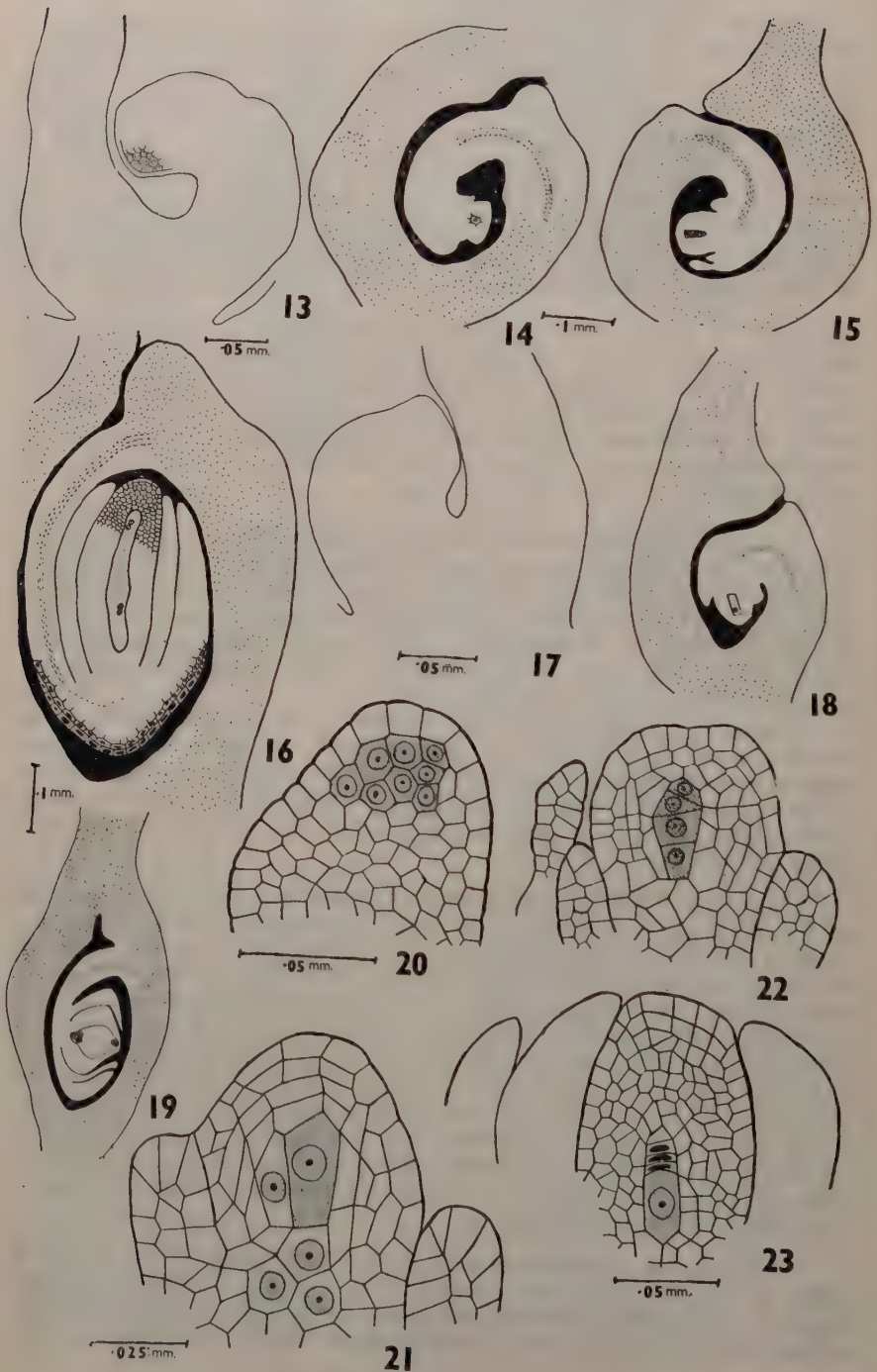
the walls of tapetal cells break down and their cytoplasm and nuclei move into the loculus and surround the pollen grains (Fig. 8). The cells of the hypodermal wall layer become radially elongated and acquire fibrous thickenings to form the endothecium. The middle layers which become compressed due to the radial elongation of the hypodermal wall layer (Fig. 11), and the epidermis persists in the mature anther.

The primary sporogenous cells divide mitotically and form a small mass of spore mother cells; they subsequently increase in size and undergo meiotic divisions. Division of pollen mother cells is successive (Fig. 6). Cytokinesis takes place by cell plate formation. Pollen tetrads are bilateral or tetrahedral. The mature pollen grains are two-celled and monocolpate (Figs. 9 and 10). Very small spinescent outgrowths are found on the exine.

Ontogeny of the carpel.—The carpellary primordium arises as a small conical protuberance on the thalamus. It later becomes cup-shaped due to differential growth. One side of the cup continues to grow and forms the style and stigma while from the other side the ovule primordium arises in a subterminal position as a lateral protuberance (Figs. 13 and 17).

The Ovule.—The ovule soon becomes bent as a result of the growth of the funiculus and comes to lie in a position facing away from the style at the megaspore mother cell stage (Fig. 18). The curvature of the ovule continues further, the rate of growth varying from species to species. In *Cinnamomum iners* at the megaspore tetrad stage (Fig. 15) or even earlier (Fig. 14) the tip of the ovule is at right angles to the style. At the four-nucleate embryo-sac stage the curvature is complete, the micropyle pointing to the style (Fig. 15). In *C. zeylanicum* the curvature is arrested early and at the mature embryo-sac stage the ovule takes a transverse position with the micropyle at right angles to the style and pointing towards the lateral wall of the gynœcium (Fig. 19). In *Litsea sebifera* at the mature embryo-sac stage the micropyle points to the style (Fig. 24).

The ovule is anatropous, pendulous, crassinucellate and bitegmic (Figs. 16, 19 and 24). The integument initials are seen in the young ovule at the primary archesporium stage (Fig. 20). The integuments are not very well developed at the megaspore mother cell stage (Fig. 21)



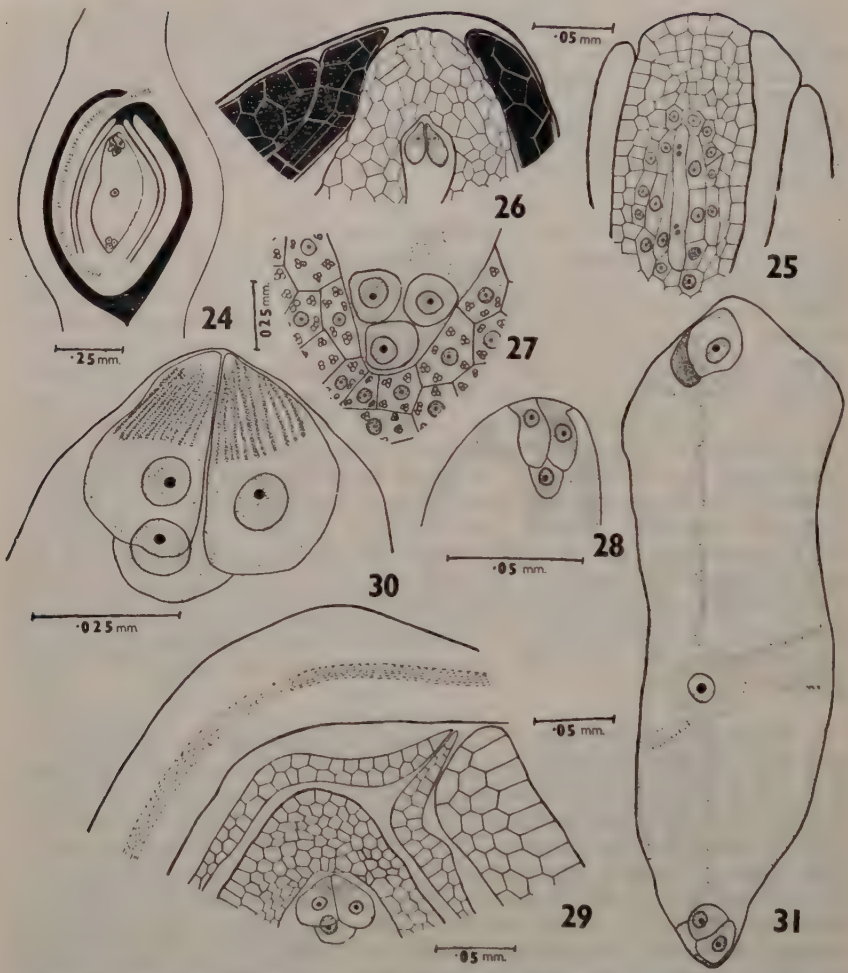
TEXT-FIGS. 13–23

TEXT-FIGS. 13–23. Fig. 13. L.s. young carpel with ovule primordium in *C. iners*. Figs. 14–16. L.s. carpel at successive stages of development showing curvature of the ovule in *C. iners*. Figs. 17–19. L.s. carpel at successive stages of development to show curvature of ovule in *C. zeylanicum*. Fig. 20. L.s. nucellus showing multicellular archesporium in *C. zeylanicum*. Fig. 21. L.s. ovule showing megaspore mother cell in *C. zeylanicum*. Note nucellar cells with prominent nuclei and nucellar epidermis with periclinal division in apical region. Fig. 22. L.s. young ovule showing linear tetrad of megaspores in *C. iners*. Fig. 23. L.s. ovule showing linear tetrad of megaspores of which the micropylar three are degenerating in *C. zeylanicum*.

but are fully formed at the tetrad stage (Fig. 22). The inner integument is three to four-layered in *Cinnamomum* (Fig. 22) and two-layered in *Litsea* (Fig. 29). In *Cinnamomum* it does not grow beyond the nucellus (Figs. 16 and 25) while in *Litsea sebifera* it extends beyond the nucellus forming an elongated micropyle (Fig. 29). In the former it is closely appressed with the nucellus on the inside and the outer integument on the outside while in *Litsea* it is free on both sides, separated from the outer integument and the nucellus (Fig. 29). In *Cinnamomum* the overarching funiculus is in close contact with the nucellus in the micropylar region (Fig. 16). In both the genera the outer integument is as high as the inner and is four to five-layered (Fig. 29). The massive funicular vascular bundle proceeds up to the chalaza (Fig. 16). In *Cinnamomum* the nucellar epidermis becomes two-layered in the apical region by periclinal division (Figs. 23 and 25). The parietal tissue is six-layered (Figs. 23 and 29) and persists till a late stage in the developing seed (Fig. 56). In *Cinnamomum iners* the nucellar cells at the chalazal (Fig. 27) and micropylar regions are filled with starch grains.

Megasporogenesis and Embryo-Sac.—A group of hypodermal cells and one or two layers of nucellus below them become differentiated into the primary archesporial cells in the young ovule (Fig. 20). Only one of them is functional and gives rise to a megaspore mother cell (Fig. 21) after cutting a parietal cell. The megaspore mother cell undergoes meiotic division and gives rise to a linear tetrad of megaspores (Fig. 22) of which the chalazal is functional while the other three degenerate (Fig. 23). The nucellar cells surrounding the developing embryo-sac have conspicuous nuclei and dense cytoplasm (Fig. 25) in *Cinnamomum iners*. In *C. zeylanicum* such cells are seen at the megaspore mother cell stage (Fig. 21). The mature embryo-sac is narrow and elongated. The synergids in *Litsea sebifera* show filiform apparatus (Fig. 30). In *C. iners* the synergids have large basal vacuoles (Fig. 26) and in *C. zeylanicum* numerous small vacuoles are seen in this region (Fig. 28). The antipodals are organized as cells; while they degenerate before fertilization in *Cinnamomum* they persist for some time after fertilization in *Litsea sebifera* (Fig. 31).

Fertilization.—The pollen grains are deposited on the stigmatic hairs. After germination there, the pollen tubes traverse down the conducting tissue of the style in an intercellular manner. After emerging from the style they travel in the funiculus and approach the embryo-sac through the micropyle. Thus fertilization is porogamous. In

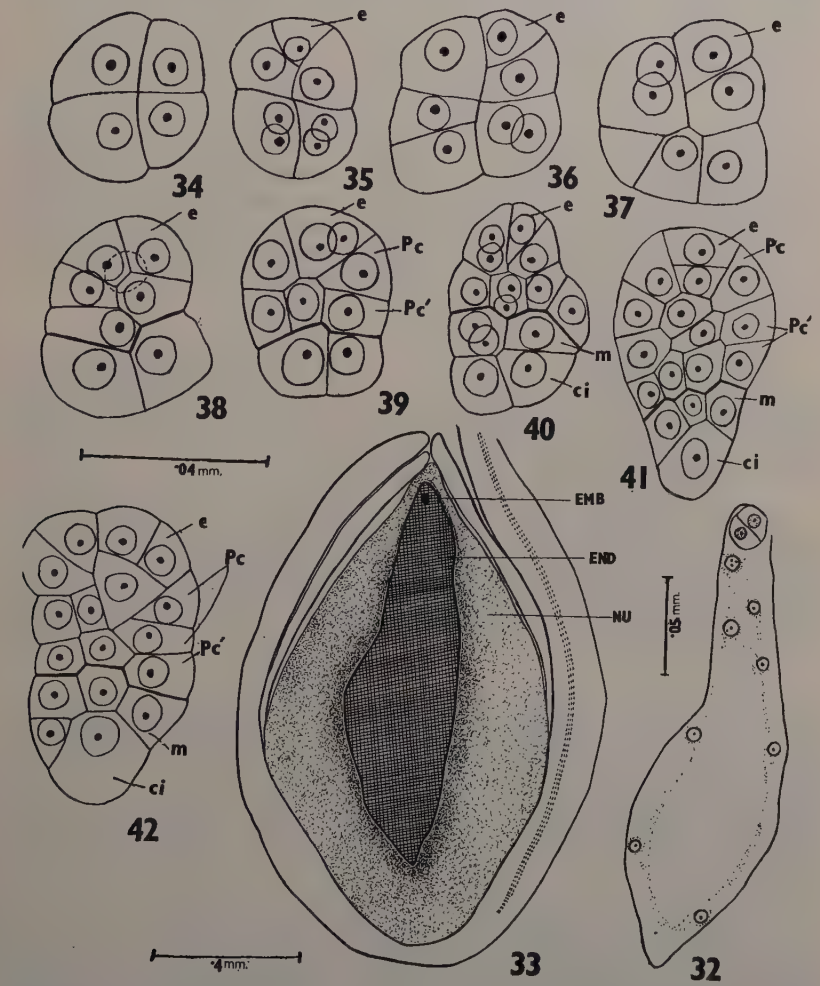


TEXT-FIGS. 24–31. Fig. 24. L.s. gynœcium of *Litsea sebifera*. Fig. 25. L.s. ovule at 4-nucleate embryo-sac stage showing nucellar cells with prominent nuclei in *C. iners*. Fig. 26. L.s. apical region of ovule showing synergids in *C. iners*. Fig. 27. L.s. chalazal region of nucellus showing antipodals in *C. iners*; note starch grains in nucellar cells. Fig. 28. L.s. apical portion of embryo-sac showing egg apparatus in *C. zeylanicum*. Fig. 29. L.s. apical region of ovule in *Litsea sebifera*. Fig. 30. L.s. apical portion of embryo-sac showing egg apparatus in *Litsea sebifera*; note filiform apparatus in synergids. Fig. 31. L.s. fertilized embryo-sac in *Litsea sebifera* showing persistent synergid and antipodals and primary endosperm nucleus.

Litsea sebifera one of the synergids persists for some time after fertilization (Fig. 31) while in *Cinnamomum* both degenerate soon after fertilization.

Endosperm.—The primary endosperm nucleus divides earlier than the fertilized egg. In *Cinnamomum* endosperm development is of the

nuclear type. At the first division of the zygote there are about eight to ten free endosperm nuclei along the periphery of the embryo-sac (Fig. 32). The nuclei are large and one, two or three nucleolate. In *Cinnamomum* the endosperm nuclei have glistening crystalline bodies at the centre, one in each when there are three nucleoli and three when there is a single nucleolus. In *Litsea* the endosperm nuclei occasionally become spindle-shaped. In *Cinnamomum* cell-wall formation commences from the micropylar end (Fig. 56) and at the globular stage of the embryo the entire endosperm becomes cellular. In *Litsea* even at



Text-Figs. 32–42. Fig. 32. L.s. embryo-sac showing endosperm nuclei and two-celled proembryo in *C. iners*. Fig. 33. L.s. young seed of *L. sebifera*. EMB—embryo; END—endosperm; NU—nucellus. Figs. 34–42. Stages in development of embryo of *L. sebifera*; explanation of lettering in text.

the four-celled proembryo stage the endosperm becomes completely cellular (Fig. 33) and whether a free nuclear stage ever exists could not be determined in the available material. The endosperm cells are thin-walled, with prominent nuclei and numerous small oil globules.

Embryo.—Embryo development has been studied in detail in *Cinnamomum iners* and *Litsea sebifera*. In *Cinnamomum iners* the first division of the zygote is transverse resulting in two superposed cells—the apical cell *ca* and the basal cell *cb* (Fig. 43). Cells *ca* and *cb* next divide by means of vertical walls resulting in a four-celled proembryo of two superposed tiers of two cells each (Fig. 44). One of the daughter cells derived from *ca* then divides by means of an oblique wall giving rise to a small triangular cell designated as the epiphyseal initial *e* (Fig. 45). At this stage, therefore, the derivatives of the apical cell are three in number and consist of one terminal epiphyseal initial and two lateral subepiphyseal cells. The epiphyseal initial remains undivided for some time and its division which is transverse or longitudinal (Fig. 50) takes place when the proembryo is several celled. By further divisions in various planes the epiphyseal initial gives rise to a group of cells (Fig. 51) which ultimately form the stem apex. The derivatives of the epiphyseal cell are distinguishable till a late stage after which they merge with the other cells of the embryo (Figs. 53–55).

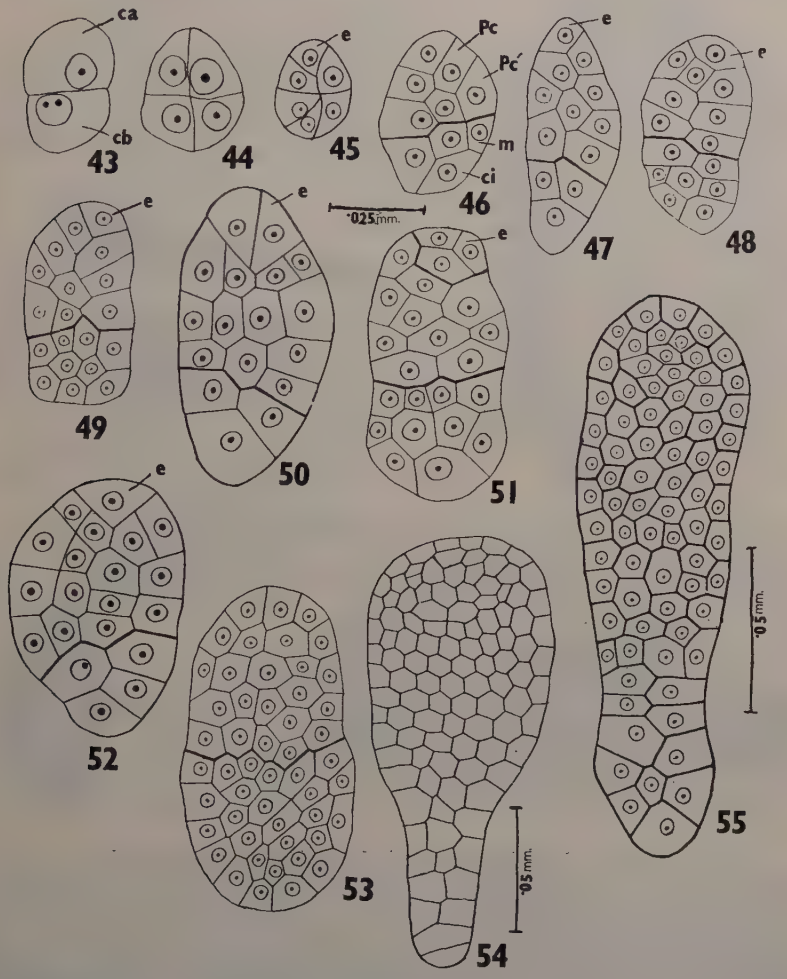
The subepiphyseal cells first divide transversely giving rise to two superposed tiers of cells, the upper *pc* and the lower *pc'* (Fig. 46). Further divisions in these two tiers are irregular (Figs. 47–52) and contribute to the formation of the central cylinder of the stem and cotyledons and the hypocotyledonary region respectively.

The two daughter cells of the basal cell divide transversely giving rise to two superposed tiers of cells, the upper *m* and the lower *ci* (Fig. 46). Occasionally division of one of the daughter cells may be oblique (Fig. 45). Tier *m* undergoes further divisions in all planes and forms the hypophyseal region. The lower tier *ci* gives rise to the suspensor (Figs. 53–55).

Since the derivatives of the apical cell of the two-celled proembryo alone contribute to the formation of the embryo proper while the suspensor and the hypophyseal region are derived from the basal cell, the embryo development conforms to the Onagrad Type. The presence of an epiphyseal initial is characteristic of only the Trifolium Variation of Johansen (1950), in which therefore this can be placed. Embryo development in *Litsea sebifera* is similar to *Cinnamomum iners* (Figs. 34–42).

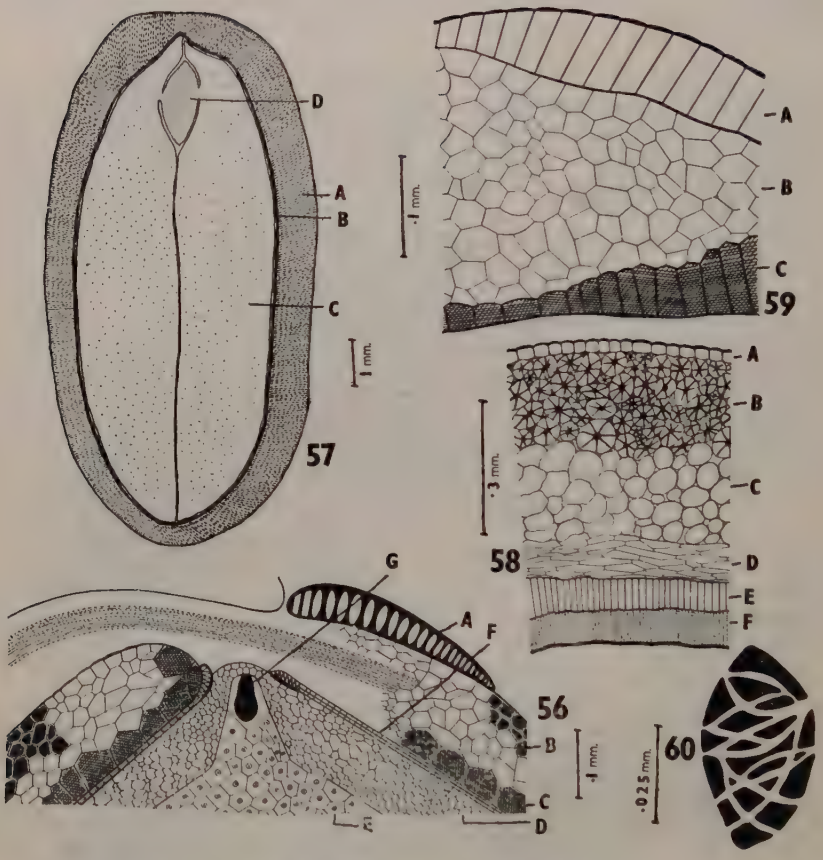
Fruit and Seed.—The fruit is long and cylindrical (Fig. 57). The cells of the inner epidermis of the fruit wall near the micropylar region of the seed radially elongate during early development (Fig. 56); later their walls become lignified and pitted, and get transformed into columnar stone cells. The mature fruit wall is therefore hard and consists of (Fig. 58) an outer epidermis, 4–5 layers of isodiametric stone cells,

4–5 layers of parenchymatous cells, about four layers of longitudinal fibres and a row of columnar stone cells derived from the inner epidermis.



TEXT-FIGS. 43–55. Stages in development of embryo of *C. iners*; explanation of lettering in text.

The seed structure is identical in all species studied. The mature seed is exalbuminous. The adult embryo fills the entire seed and has two massive cotyledons (Fig. 57) enclosing the radicle and plumule which shows leaf primordia. It shows differentiation of procambial vascular supply. In the fertilized ovule the outer integument is many-layered while the inner is two- to four-layered. After fertilization the inner integument gradually disintegrates and is absent in the mature seed. On the other hand the outer integument gradually increases



TEXT-FIGS. 56–60. Fig. 56. L.s. apical portion of young seed of *C. iners*. A—stone cells; B—outer integument; C—cells with helical thickenings; D—nucellus; E—endosperm; F—inner integument; G—embryo. Fig. 57. L.s. mature fruit of *C. zeylanicum*. A—fruit wall; B—seed-coat; C—cotyledons; D—plumule. Fig. 58. L.s. mature fruit wall and seed-coat of *C. zeylanicum*. *A*—outer epidermis; B—stone cells; C—parenchymatous cells; D—fibrous cells; E—columnar stone cells; F—seed-coat. Fig. 59. L.s. mature seed-coat of *C. zeylanicum*. A—outer epidermis; B—parenchymatous cells; C—inner epidermis cells with helical thickenings. Fig. 60. An inner epidermal cell of the seed-coat of *C. zeylanicum* in surface view showing helical thickenings.

in thickness mainly by cell enlargement and its outer and inner epidermal cells elongate radially (Fig. 59) while the outer epidermal cells become filled with tannin. The cells of the inner epidermis acquire band-shaped helical thickenings (Fig. 60). In between them there are eight to ten layers of parenchymatous cells.

Summary

The paper deals with the embryology of *Cinnamomum iners* *C. zeylanicum* and *Litsea sebifera.*

The anthers are two-celled in all species studied. The mature anther wall is five-layered including the epidermis. The innermost layer forms a tapetum of periplasmodial type. The tapetal cells are usually binucleate but in *Cinnamomum zeylanicum* they sometimes become tetranucleate. Division of pollen mother cells is successive. Mature pollen grains are two-celled, monocolpate and spinescent.

The gynœcium consists of a carpel with a single anatropous, pendulous, crassinucellate, bitegmic ovule. In *Cinnamomum* the inner integument does not grow beyond the nucellus and the funiculus plugs the micropyle formed by the outer integument. The outer integument is several-layered and the inner is four-layered in *Cinnamomum* and two layered in *Litsea.* The archesporium in the ovule is multicellular. However, only one embryo-sac is formed according to the Polygonum type. The synergids show filiform apparatus in *Litsea.* The antipodals are ephemeral in *Cinnamomum* and persistent in *Litsea.*

Endosperm is of the nuclear type in *Cinnamomum* and becomes cellular from very early stages in *Litsea.*

Embryo development conforms to the Onagrad type and keys out to the Trifolium Variation. The mature embryo has two very massive cotyledons enclosing the radicle and plumule which shows the first leaf primordia.

The pericarp consists of an outer epidermis, 4–5 layers of stone cells, 4–5 layers of parenchymatous cells, about four layers of longitudinal fibres and a layer of columnar stone cells derived from the inner epidermis. The inner integument completely disappears in the mature seed while the outer which forms the seed-coat consists of an epidermis of radially elongated cells, a few layers of parenchyma and an inner epidermis of radially elongated cells whose walls show helical thickenings.

Acknowledgements

The author's thanks are due to Professor J. Venkateswarlu for his guidance and help, Professor P. Maheshwari for kindly loaning literature from his personal library, Mr. R. Seshagiri Rao for the materials of *Cinnamomum iners* and *Litsea sebifera*, Mr. B. S. M. Dutt for material of *Cinnamomum zeylanicum* and Mr. P. S. Prakasa Rao for drawing some illustrations (Figs. 26, 33, 38 and 59).

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ON THE DIFFERENTIATION OF A AND B CHROMOSOMES OF *SORGHUM PURPUREO-SERICEUM* AT PACHYTENE

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Introduction

The presence of supernumerary or B chromosomes in *Sorghum purpureo-sericeum* was discovered by Janaki-Ammal (1939), who later presented data on their frequency in a population of 100 plants. No distinction has been made of any difference in morphology underlying these chromosomes. In a re-examination of the same material, Darlington and Thomas (1941) found three different types of B chromosomes: one similar in length to the " regular " chromosomes, one very short chromosome, and a very long iso-chromosome with identical arms. No synapsis was observed between B chromosomes of different morphology or between B and " regular " chromosomes.

Garber (1950) studied six collections of this species and found long and short types of B chromosomes in two of them. He further noted that the short B chromosome is approximately half as long as the long B chromosome at metaphase I (*cf.* Garber, 1950, Pl. 45, *d*).

None of the above investigations include a study of these A and B chromosomes at pachytene since this stage of meiosis in this species does not usually lend itself to a critical cytological study. However, Darlington and Thomas (1941) have mentioned that pachytene in " plus " plants shows large blocks of heterochromatic material resembling B chromosomes of *Zea mays*. Repeated attempts by the author to study this stage has resulted in the finding of certain plants in the populations raised out of two collections made in this country in which pachytene chromosomes were found exceptionally well spread out permitting the detailed analysis of the five A chromosomes and two types of B chromosomes. The two types of B chromosomes studied here can be identified with the medium and short B chromosomes described by Darlington and Thomas (1941), and the long and short B chromosomes found by Garber (1950).

Such a study might throw considerable light on some of the important problems that have a direct bearing on the B chromosomes such as their structure, origin, mutual relationship, pairing properties and the nature of the region responsible for their non-disjunction at pollen mitosis.

The present paper deals with the results obtained from the detailed analysis of the entire A chromosome complement and two types of B chromosomes at pachytene, and describes in detail, their relative lengths, size, shape, sequence and stainability of the chromomeres.

Material and Methods

The material used in this investigation has been derived from 50 plants in the populations raised out of two collections. The entire inflorescence from each plant was fixed in 1 : 4 acetic alcohol for 4 hours, it is then passed to 95% alcohol, where it was kept overnight, and then passed to 70% alcohol and kept in a Frigidaire until used for study.

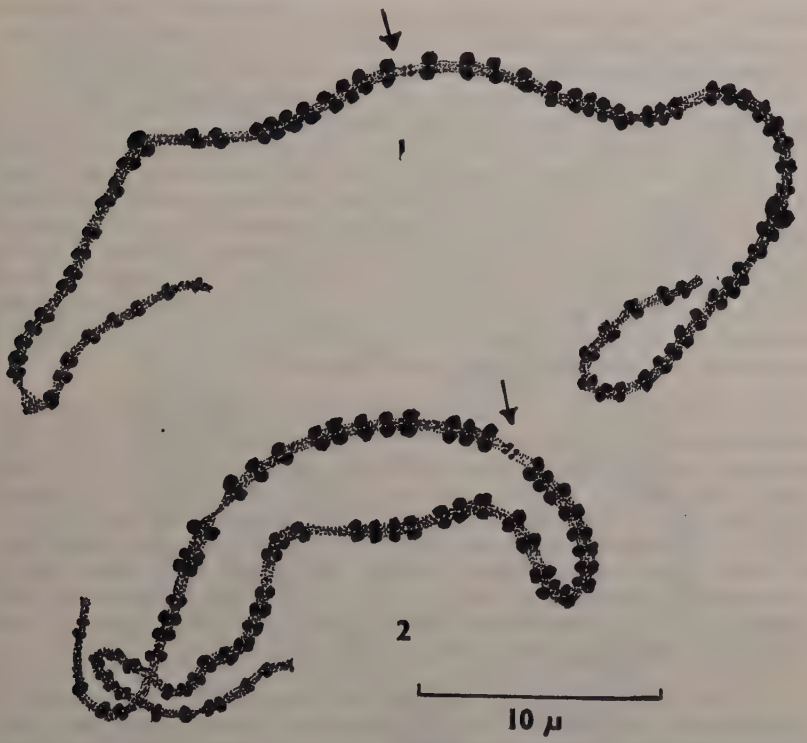
Pachytene preparations were made according to the modified acetocarmine technique developed by Lima-de-Faria (1948) for the study of the pachytene chromosomes of rye. Preparations made out of this technique showed cells with exceptionally well spread out pachytene chromosomes with distinct differentiation of the chromosome body into median heavily stained segments composed of chromomeres of larger size that show a gradual decrease in size and stainability towards the distal ends of the arms.

Photomicrographs presented in this paper were taken from fresh preparations using a Gamma Microflex Photomicrographic apparatus with a lens combination of 90 X apochromatic oil immersion objective and 12·5 X eye-piece. The negatives and positives were made employing Kodak B 20 plates and Kodak 3 S and 4 S glossy bromide paper respectively.

A Chromosomes at Pachytene

The five A chromosomes of *S. purpureo-sericeum* are in general characterized by the following, *viz.*: (1) The differential stainability of the five A chromosomes display a structural differentiation of the chromosome body into median heavily stained regions composed of chromomeres of larger size that show a gradual decrease in size and stainability towards the distal ends of the arms. (2) This inherent structural differentiation of the chromosome delimits the centromere positions that were also found to be composed of light staining chromomeres. This can be made out in the well-stained cells. (3) The general gradient of chromomere size apparently originating on both sides of the centromeres in all the A chromosomes excepting the short arm of the nucleolar-chromosome is further interrupted at rather irregular intervals by chromomere pairs of comparatively larger size in certain chromosomes. These form useful cytological markers in the identification of the chromosomes carrying them. (4) No knob formations of the kind found in the pachytene chromosomes of rye or *Zea mays* have been encountered in anyone of the five chromosomes of the complement. (5) Each chromosome pair in *S. purpureo-sericeum* at pachytene, thus, appears as structural unity at the microscopic level.

The regular complement at pachytene has been studied in considerable detail with respect to their relative lengths, size, shape and



TEXT-FIGS. 1–2. Chromosomes 1 and 2 respectively of the regular complement at pachytene. Arrows point to Centromeres. Drawn from Plate XVII, Fig. 1.

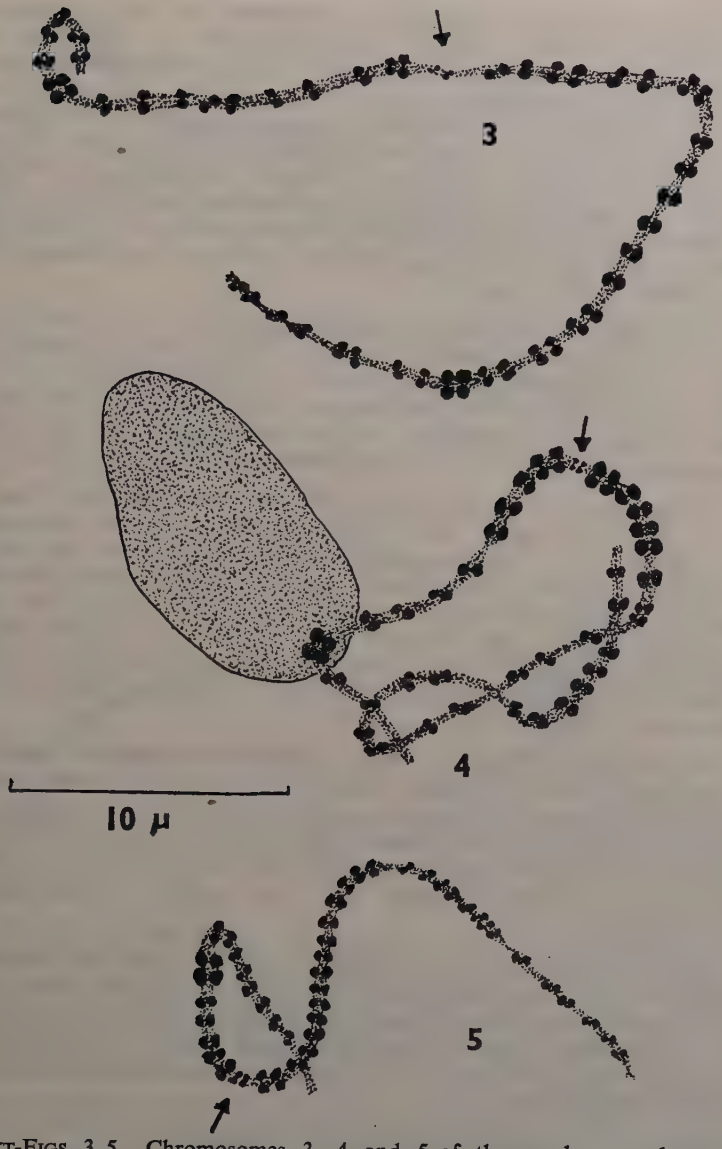
stainability of the chromomeres and their general disposition in the five chromosomes. Only in two cells it was found possible to study all the five chromosomes although camera lucida diagrams of the individual chromosomes have been made from several cells. In the typically stained cells (Plate XVII, Figs. 1 and 2) the five A chromosomes of the complement can be seen to show the characteristic chromomere differentiation into median larger ones, followed by chromomeres that show a gradual decrease in size and stainability. The centromere regions were found to be situated in all the five chromosomes in the heavily stained sub-median segments. The chromomeres following these heavily stained regions show a gradual decrease in size and stainability until the distal ends of the arm is reached, where the chromomeres are so faintly stained making it difficult to demarcate them from the fibrillæ. This phenomenon of chromomere gradation in the pachytene chromosomes is described in a number of plants like *Fritillaria eggeri*, *F. imperialis*, *F. verticillata*, *F. obliqua*, *F. pontica*, *F. ornensis* (Darlington, 1935), *Veltheimia viridifolia* (Coleman, 1940), *Hordeum vulgare* (Moh and Nilan, 1954), *Solanum lycopersicum* (Brown, 1949; Barton, 1950; Gottschalk, 1951) and *Plantago ovata* (Hyde, 1953). Recently, Lima-de-Faria (1956) has given an account of our present knowledge of this

aspect. The short arm of the nucleolar-chromosome in *S. purpureo-sericeum* forms an exception to this general rule in that the entire arm is composed of more or less chromomeres of equal staining ability, in contrast to the long arm where the chromomeres show the general decrease in size and stainability until the distal end of the arm is reached (Plate XVII, Fig. 1 and Text-Fig. 4). The nucleolar-organising region is found to be constant in position and is located in the distal region of the short arm and consists of two pairs of chromomeres placed very near to each other. In general the entire short arm of this chromosome is characterized by the heavily stained chromomeres distributed in two deeply stained segments. The region of the long arm adjacent to the centromeres was seen to be composed of deeply stained chromomeres confined to a single segment followed by chromomeres that show a gradual decrease in size towards the distal end of the arm.

The remaining four A chromosomes that constitute the complement are in general characterized by the presence of particularly large chromomeres on either side of the centromere regions followed by chromomeres that show a gradual decrease in size and stainability towards the distal ends of the arms (Plate XVII, Figs. 1 and 2 and Text-Figs. 1–3 and 5). Corresponding to the gradient of chromomere size characteristic of all the A chromosomes with the exception of the short arm of the nucleolar-chromosome, the spacing of the two consecutive chromomeres in the chromosome body shows a gradual decrease with increasing size of the chromomeres.

In the slides of average staining the centromere regions of the A chromosomes were found to be apparently structureless gaps with heavily stained chromomeres on either side of them. In these regions the observed intensity of the stain was found to be similar to that found in the distal region of the arm where the chromomeres can be hardly distinguished from the fibrillæ to which they are attached. Repeated attempts to increase the intensity of the stain in the chromomere regions has resulted in the finding that the centromere regions in all the five A chromosomes of the regular complement were composed of a definite structure.

In the structural organisation of the centromeres the following parts have been noticed, starting from one end of the centromere: a pair of lightly stained fibrillæ, a chromomere pair, a pair of deeply stained fibrillæ, another chromomere pair and again an almost unstained fibrilla pair. Such a structure has been identified in each of the five chromosomes of the regular complement particularly in well-stained cells, and is found to be essentially alike in all. During the recent years studies on living material made on the structural organisation of the centromere regions in a number of plants have resulted in establishing a fundamental pattern of the organisation of the centromeres in general (Lima-de-Faria, 1956). The long B chromosome pair to be described later is also found to possess a similar structure in the organisation of the centromere region conforming to the basic pattern described above for all the regular chromosomes.



TEXT-FIGS. 3–5. Chromosomes 3, 4 and 5 of the regular complement at pachytene. Drawn from Plate XVII, Figs. 1, 2. Arrows point to centromeres.

The main characteristics of the five regular chromosomes that make it possible to distinguish anyone of the chromosomes from the other members of the complement are given below. The data accompanying the description of the individual chromosomes is based upon 10 measurements made for each of the 5 chromosomes including two cells in which the entire complement has been analysed end to end.

Chromosome 1.—The longest chromosome in the complement measuring on an average $75{\cdot}0 \pm 2{\cdot}2\,\mu$ (Text-Fig. 1). The short and long arms found to measure $30{\cdot}6$ and $44{\cdot}4\,\mu$ respectively with an arm ratio of 0·69 expressed as S.A./L.A. The centromere region was found to be $2{\cdot}2\,\mu$ in length. Sometimes it is found difficult to distinguish this from the succeeding chromosome due to the fact that it comes very near to it in length. However, two pairs of heavily stained chromomeres of comparatively larger size than the adjacent ones in either arm situated in the half-way positions were found. This serves as a diagnostic feature for the identification of this chromosome from chromosome 2 (Text-Fig. 1).

Chromosome 2.—Measures on an average $72{\cdot}2 \pm 2{\cdot}5\,\mu$ with a short arm of $33{\cdot}3\,\mu$ and long arm of $38{\cdot}9\,\mu$. The arm ratio is found to be 0·86. The centromere region measures on an average $1{\cdot}39\,\mu$. No particular seriations of the chromomeres have been noticed, the decrease in size and stainability of the chromomeres being uniform throughout in both the arms of the chromosome (Text-Fig. 2).

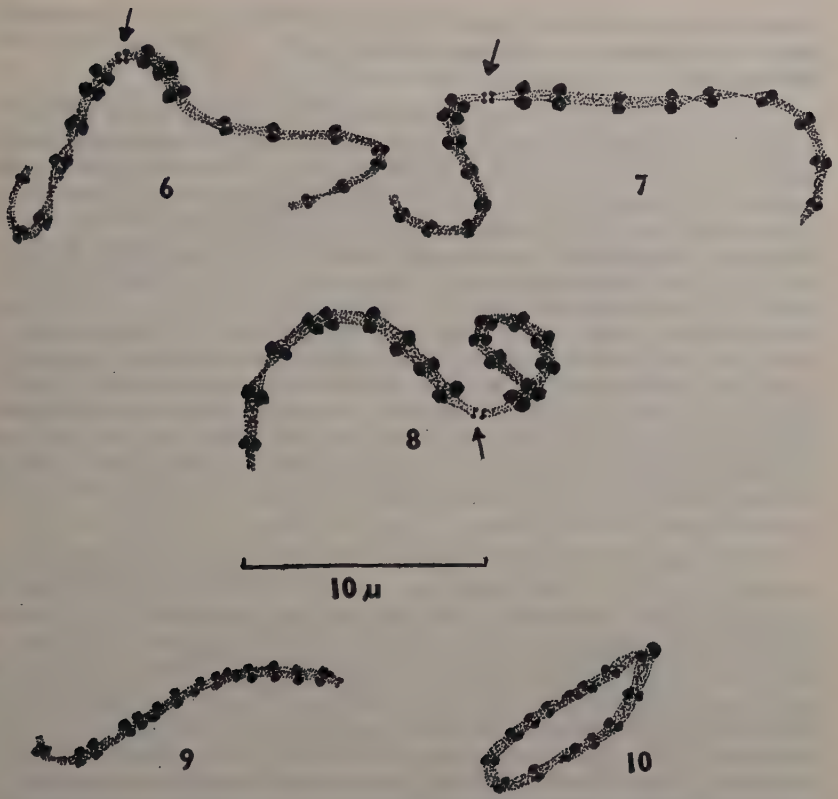
Chromosome 3.—On an average this chromosome was found to be $55{\cdot}6 \pm 1{\cdot}9\,\mu$ in length, with a short arm of $22{\cdot}2\,\mu$ and long arm of $33{\cdot}4\,\mu$ respectively. The arm ratio is found to be 0·66. The centromere region measures $2{\cdot}78\,\mu$, which is comparatively a high value when the corresponding values for the remaining A chromosomes are taken into consideration. The presence of two pairs of heavily stained chromomeres of comparatively larger size than the adjacent ones in the long arm towards the distal end forms a diagnostic feature of this chromosome (Text-Fig. 3).

Chromosome 4.—This is the nucleolar-chromosome with an average length of $52{\cdot}8 \pm 2{\cdot}6\,\mu$. Arm ratio is 0·58 with a short arm of $19{\cdot}4\,\mu$ and long arm of $33{\cdot}4\,\mu$ on an average. Centromere region was found to measure $1{\cdot}39\,\mu$ in length. The distal region of the short arm beyond the nucleolar-organising body was found to measure $5{\cdot}6\,\mu$ and was seen to be composed of two pairs of chromomeres (Text-Fig. 4).

Chromosome 5.—On an average this chromosome was found to measure $36{\cdot}1 \pm 1{\cdot}6\,\mu$ with a short arm of $13{\cdot}9\,\mu$ and the long arm of $22{\cdot}2\,\mu$ respectively. The arm ratio is found to be 0·63. The region of the centromere measures on an average $1{\cdot}39\,\mu$. In its uniform decrease in size and stainability of the chromomeres this chromosome resembles chromosome 2.

B Chromosomes at Pachytene

Out of the several cells examined at pachytene it was found possible to study the two types of B chromosomes end to end only in a few cells. The two types of B chromosomes studied here can be identified with the short and medium B's described by Darlington and Thomas (1941), and the long and short B chromosomes found by Garber (1950). The short B (Plate XVII, Fig. 3 and Text-Fig. 9) was found at pachytene as a fold-back configuration with the apparent pairing of the arms. The



TEXT-FIGS. 6–10. Figs. 6–8. Long B chromosome pair at pachytene. Arrows point to the centromeres. Fig. 9. Short B chromosome at pachytene as a fold-back configuration. Fig. 10. Short B chromosome at pachytene forming the ring configuration in one plant.

pairing of the arms of the short B chromosome is of considerable interest in view of its presumed iso-chromosome structure as suggested by Darlington and Thomas (1941). The average length of the fold-back configuration of the short B chromosome at pachytene is found to be $17{\cdot}0\,\mu$ on the basis of ten measurements taken. No pronounced knobs have been noticed in any region of the two B chromosomes studied. The centromere position in the short B chromosome is presumably at the distal end of the fold-back configuration where the heavily stained segment is situated. In about 25% of the cells examined in one plant the short B chromosome was found to form a characteristic ring configuration (Plate XVII, Fig. 4 and Text-Fig. 10). Presumably there is a certain amount of affinity between the particles in the centromere region and those located in the distal region of the arms. However, the configuration corresponding to the ring at pachytene has not been encountered at diakinesis and metaphase I, the short B appearing invariably as a univalent at these stages. No distinct structure has

been observed in the centromere region of the short B chromosome due to difficulties in obtaining differentiation in this region of the chromosome.

The long B chromosome pair shows complete synapsis at pachytene with an average length of 38·5 μ on the basis of ten measurements taken (Plate XVII, Fig. 5 and Text-Figs. 6–8). Its ready identification is rendered possible by its marked heterochromatic nature. The centromere region is found to clearly defined as distinct gap in the cells of average staining while in the heavily stained cells the centromere region was also found to be composed of two pairs of light staining chromomeres. The delimitation of the centromere region in this long B chromosome pair is found to be considerable help in demarcating the long arm from the short arm. In the short arm adjacent to the centromere are found a pair of heavily stained chromomeres which together form a characteristic segment that was found to be of considerable help in distinguishing the short arm from the long arm. In the long arm adjacent to the centromere are found a series of three deep staining chromomere pairs followed by seven chromomere pairs of more or less same size and stainability.

The centromere region consists of two pairs of chromomeres (Plate XVII, Fig. 5 and Text-Figs. 6–8). The fibrillæ connecting the centromeric chromomeres to the arms can be seen to be lightly stained while the intermediary region between the chromomere pairs constitutes the dark staining region. It is therefore possible to resolve the region of the centromere into three zones: the exterior zone connecting the centromeric chromomeres to arms and is composed of light staining fibrillæ, the middle zone consisting of two pairs of chromomeres and finally the interior zone composing the space between the two pairs of chromomeres. Thus the structural organisation of the centromere region is found to be essentially alike at the microscopic level with that seen in the case of A chromosomes. However, the phenomenon of chromomere size gradient so characteristically seen in the case of A chromosomes with the exception of the short arm of the nucleolar-chromosome is absent in the case of B chromosomes.

Discussion

As already pointed out from the evidence obtained in the analysis of the A chromosomes with the exception of the short arm of the nucleolar-chromosome, the A chromosome complement in *S. purpureo-sericeum* at pachytene is characterized by the general decrease in chromomere size and stainability on either side of the centromeres. This phenomenon has been termed chromomere size gradient and is found in a number of plants including rye (Lima-de-Faria, 1952 *b*). On the basis of the inverse proportionality between the chromomere size and the distance from the centromere in *Agapanthus* and rye Darlington (1933), and Lima-de-Faria (1952 *b*) have proposed that this gradient is controlled by some substance diffusing out from the centromere. In the present study of the pachytene chromosomes of *S. purpureo-sericeum* the centromeres in each chromosome seems to

influence the phenomenon of chromomere size gradient characteristic of all the five regular chromosomes with the exception of the short arm of the nucleolar-chromosome although the details of the mechanism could not be ascertained.

Darlington and Thomas (1941) have attributed the abnormal behaviour of the B chromosomes at mitosis to the inadequacy of the centromeres in contrast to the regular chromosomes. The present study on the pachytene chromosomes, however, do not point to any positive difference in the structural organisation of the centromeres in the A and B chromosomes, there being an essential similarity at the microscopic level in the structural organisation of the centromeres conforming to a basic pattern described above. In this respect the present observations parallel the situation in the A and B chromosomes of rye. In rye the structure of the centromeres in both A and B chromosomes conforms to a basic pattern (Lima-de-Faria, 1952 *a*), which is essentially similar to that found in the present study. It therefore appears to the author at the present stage of investigation, that the abnormal behaviour of the B chromosomes in *S. purpureo-sericeum* at mitosis and their non-disjunction at second pollen mitosis is more likely to be due to their marked heterochromatic nature when compared to the regular chromosomes.

The present observations on the two types of B chromosomes and on the entire A complement at pachytene in *S. purpureo-sericeum* are of considerable interest in the light of our knowledge pertaining to the pachytene chromosome in the genus *Sorghum*. They seem to occupy in respect of their structural differentiation and stainability an intermediary position between the uniformly stained pachytene chromosomes of *S. intrans* described by Garber (1947) and the differentiated pachytene chromosomes of *S. subglabrescens* (Venkateswarlu and Ramakrishna Reddi, 1956) in which the proximal regions are heavily stained with acetocarmine while in the distal regions the chromomeres cannot be distinguished from the fibrillæ. The region of transition is, however, characterized in the case of chromosomes 4 and 5 by the presence of a series of chromomeres that were taken to be useful cytological criteria for the identification of those chromosomes in the complement.

The problem of the origin of the B chromosomes is not known with certainty in any of the three plants, namely, maize (McClintock, 1933), rye (Lima-de-Faria, 1952 *b*), and *Festuca pratensis* (Bosemark, 1950) in which their fine structure has been studied at pachytene. In maize, Randolph (1941) has pointed out that there is a considerable diversity among the A chromosomes in the different strains investigated and that further studies of similar character may yield valuable clues to the origin of B chromosomes. In rye, however, Lima-de-Faria (1952 *a*) has found that the short arm of the nucleolar-chromosome of Swedish origin showing a certain degree of similarity to the standard fragment (a type of B chromosome) and that this apparent similarity is found to be further accentuated in the short arm of the nucleolar-chromosome from a Turkish strain.

In the present study the A and B chromosomes of *S. purpureo-sericeum* at pachytene do not show any degree of similarity in their structural differentiation with any one of the arms of the A chromosome complement or a segment thereof equal in length to that in either short or long arms of the B chromosome pair. The degree of difference between the A and B chromosomes has evolved to such an extent that a direct similarity cannot be found between the B and A chromosome regions at the present stage of investigation.

Summary

(1) The five A chromosomes and two types of B chromosomes in *Sorghum purpureo-sericeum* have been analysed at pachytene with respect to their size, shape, sequence and stainability of the chromomeres composing them. The analysis permitted the identification of the entire A chromosome complement and two types of B chromosomes.

(2) The A chromosome complement is characterized by the phenomenon of chromomere size gradient on either side of the centromeres with the exception of the short arm of the nucelolar-chromosome which is considered to be controlled by the direct influence of centromeres.

(3) A definite structure in the centromere regions of both A and B chromosomes has been found conforming to a basic pattern. In the structural organisation of the centromeres at the microscopic level in both A and B chromosomes there seems to be marked difference. This finding points to the conclusion that the causal factor underlying the abnormal behaviour of the B chromosomes at mitosis and their non-disjunction at second pollen mitosis is more likely to be due to their marked heterochromatic nature rather than to the inadequacy of the centromeres in them.

Acknowledgements

The author wishes to express his sincere thanks to Prof. J. Venkateswarlu for his guidance and encouragement throughout the work. Further he is thankful to him for obtaining a supply of the seeds of materials used in this investigation from Dr. L. S. S. Kumar, Economic Botanist to Government, Bombay State, Poona, and Sri. G. B. Deodikar, Maharashtra Association for the Cultivation of Science, Poona-4, to whom also his thanks are due. His thanks are also due to Ministry of Education, Government of India, for the award of Senior Research Scholarship, during the tenure of which this work was carried out.

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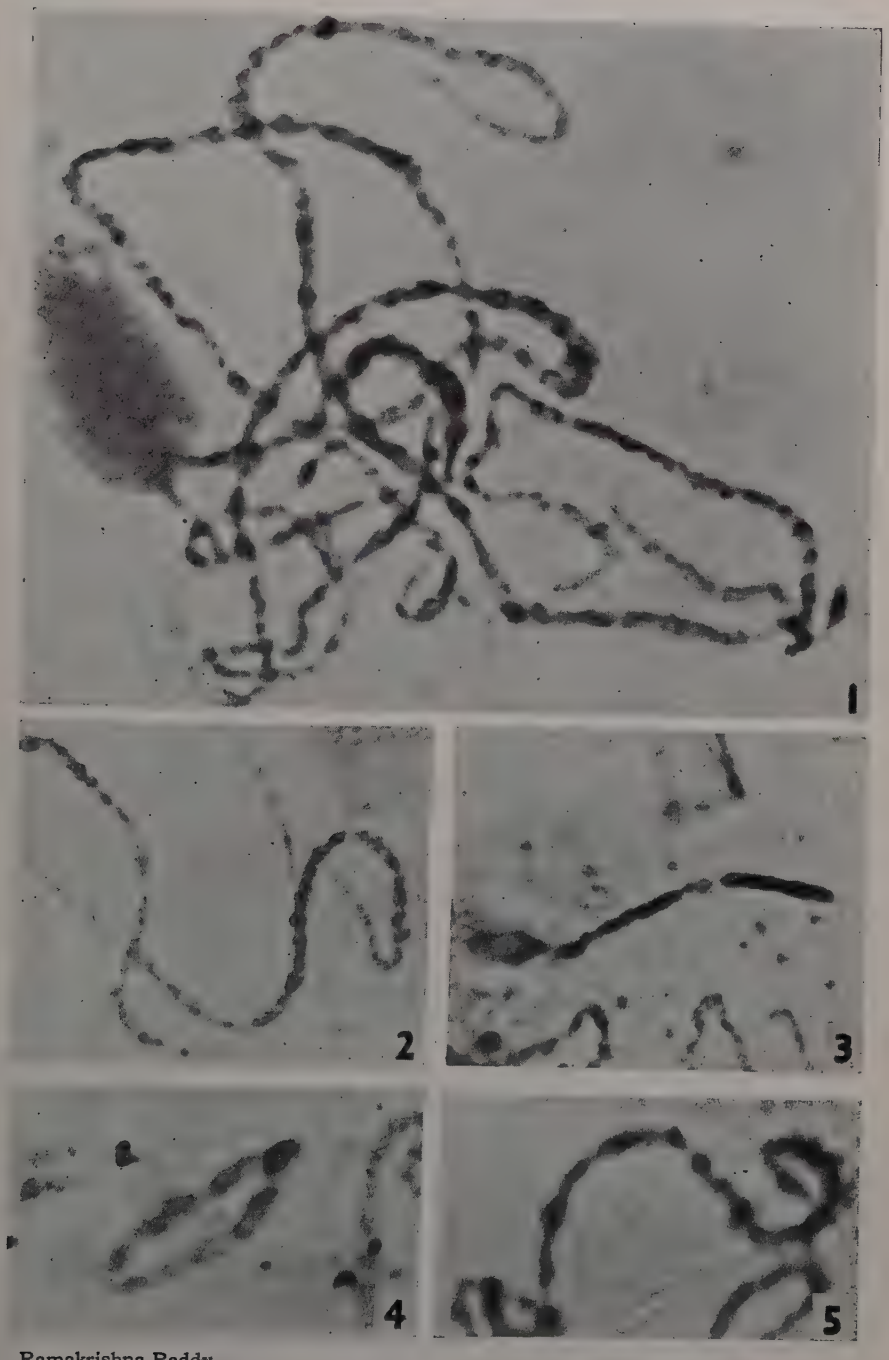

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EXPLANATION OF PLATE XVII

FIG. 1. Pachytene stage showing 1–4 regular chromosomes. × *ca.* 3,050.

FIG. 2. Fifth regular chromosome at pachytene, × *ca.* 3,050.

FIG. 3. Fold-back configuration formed by the short B chromosome at pachytene. × *ca.* 3050.

FIG. 4. Ring configuration formed by the short B chromosome at pachytene. × *ca.* 3,050.

FIG. 5. Long B chromosome pair at pachytene showing complete synapsis × *ca.* 3,050.

MALE AND FEMALE GAMETOPHYTES IN FOUR SPECIES OF *ASPARAGUS*

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Introduction

Liliaceæ is one of the largest families of monocotyledons, comprising two hundred and fifty genera and three thousand seven hundred species (Willis, 1951). On account of the occurrence of several features of embryological importance and also on account of the presence of large nuclei and chromosomes which lend themselves to be studied easily it received considerable attention from students of morphology and cytology since a long time and an extensive literature concerning these aspects is now available.

Asparagoideæ is one of the eleven subfamilies recognised by Engler (Willis, 1951) and comprises the tribes Asparagæ, Polygonatæ, Convallarieæ and Parideæ. Most of the previous work on the embryology of this subfamily is confined to the tribes Polygonatæ, Convallarieæ and Parideæ. The embryology of the tribe Asparagæ consisting of the single genus *Asparagus* has remained comparatively little investigated. Schnarf (1931) mentions about two-celled pollen grains at the time of shedding, formation of parietal cells by the archesporium of the ovule and the development of a Normal type of embryo-sac in *Asparagus officinalis* L. Flory (1932) studied megasporogenesis and embryo-sac development in *A. officinalis* and Robbins and Borthwick (1928) gave an incomplete account of the embryo development in the same species.

The present work deals with the study of male and female gametophytes in four species of *Asparagus*, namely, *A. racemosus* Willd., *A. officinalis* L., *A. sprengeri* Regl., and *A. plumosus* Baker.

Review of Literature

Schnarf (1931) gave a brief summary of the extensive work done in the family till then and later Joshi (1939) summarised the important work done in this family till 1938. The more important work done subsequently is briefly summarised below.

In 1939 Joshi reported the occurrence of three types of embryo-sac development, namely, Normal, Scilla and a type intermediate between Normal and Scilla in the case of *Iphigenia indica*. He (1940) also found

that a Fritillaria type of embryo-sac development takes place in *Gagea fasicularis* (*lutea*). The same type of development was found to occur in *Erythronium japonicum* by Oikawa (1940) and in *E. helenæ* and *E. tuolumnense* by Cave (1942).

F. H. Smith (1943) investigated the embryo-sac development of *Clintonia uniflora* and established the similarity in development of the same with that of *C. borealis* (Oenothera type) reported previously by R. W. Smith (1911). Subsequently Walker (1944) also established the same type of embryo-sac development for *C. umbellata* and *C. andrewsiana*. Swamy (1946) in a note on the embryo-sac of *Clintonia* also supports the view of Smith and Walker that the embryo-sac of *Clintonia* develops according to the Oenothera type, thus contradicting the suggestion of Maheshwari (1937) that a reduced Fritillaria type of embryo-sac development occurs in this plant. However, Maheswari (1946 and 1947) reasserted that the embryo-sac of *Clintonia* should be regarded as a reduced Fritillaria type. Bellows and Bramford (1941) reported a Fritillaria type of embryo-sac development in a variety of *Tulipa* called " Ingles Comb Yellow ".

Randall and Rick (1945) in an investigation of polyembryony in *Asparagus officinalis* studied 405 multiple seedlings. Out of these 97% were twins, 11% triplets and 1% quadruplets. A study of chromosome numbers in the various seedlings revealed the presence of haploids, diploids, triploids, trisomics and tetraploids. From a study of chromosome numbers, stem colour and distribution of sexes the authors analysed the possible origin of the multiple seedlings.

Eunus (1950) reported a Drusa type of embryo-sac development in *Smilacina stellata* and contradicted the previous observations of Mc Allister (1909, 1914) who recorded an Adoxa type of embryo-sac development in the same. Govindappa and Sheriff (1951) reported a Polygonum type of embryo-sac development in *Scilla indica*. This is the first record of a Normal type of embryo-sac development in *Scilla* since all the previous observations established an Allium type for the rest of the investigated species. Sulbha (1954), while confirming the observations of Govindappa and Sheriff on *Scilla indica* also recorded a Polygonum type of embryo-sac development for *Scilla hyacinthina*.

Stenar (1949, 1950 and 1951) gave a list of the Liliaceæ which shows a Helobial type of endosperm development. In 1953 he recorded a Drusa type of embryo-sac development in *Smilacina triflora* and a modified Allium type in *Polygonatum odoratum* and *P. latifolium*. In the same paper he established a Polygonum type of embryo-sac for *Polygonatum verticillatum* and *Theropogon pallidus*. Further, the same author reported a Normal type of embryo-sac development in *Luzuriaga latifolia* (1953).

Sulbha (1954 *a*) undertook a reinvestigatin of *Ipl.igenia indica* and reported that only Polygonum type of embryo-sac development occurs in this, thus contradicting the earlier findings of Joshi (1939). Govindappa (1955) described the female gametophyte of *Alœ ciliaris*

to be developing according to the Normal type contradicting the report of an Adoxa type in this by Gioelli (1930).

Recent embryological studies on *Phormium tenax* by Cave (1955) support the separation of this genus from Hemerocallideæ of Liliaceæ of Engler and Prantl (1934). Further, based on the same observations, the author suggests that *Phormium* and *Doryanthes* (which show some embryological similarities between themselves) should not be included in Agavaceæ as suggested by Hutchinson (1934).

Material and Methods

Material of all the species was collected from the plants growing in the Botanical Gardens of the Andhra University. The material was fixed in either acetic alcohol or formalin acetic alcohol. Customary methods of dehydration and infiltration were followed and the material was embedded in paraffin wax. Sections were cut at thickness ranging from 10 to 20 μ and stained in Delafield's Hæmatoxylin or Heidenhain's Iron Alum Hæmatoxylin followed by destaining in picric acid. The later method gave the best results.

Observations

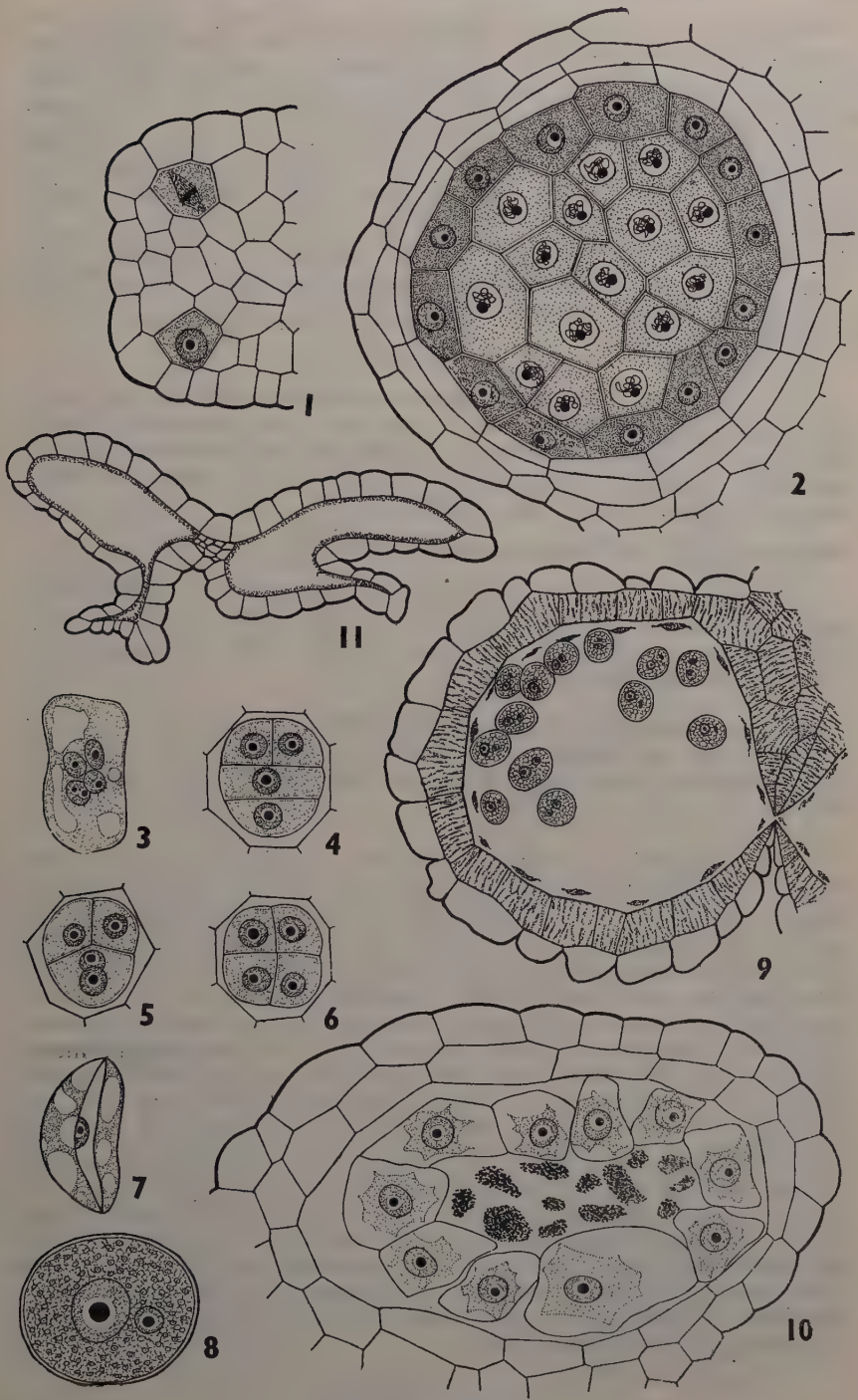
A common account of the microsporogenesis and male gametophyte and megasporogenesis and female gametophyte for all the species is given below as they are essentially similar in respect of them.

Microsporogenesis and male gametophyte

The primary archesporium consists of a single layer of hypodermal cells in each lobe of the young anther (Fig. 1). They soon divide periclinally giving rise to a layer of parietal cells and a layer of primary sporogenous cells to the inside (Fig. 1). Three wall layers are developed below the epidermis as a result of periclinal divisions in the primary parietal cells (Fig. 2). Of these, the innermost develops into the anther tapetum while cells of the sub-epidermal wall layer develop fibrous thickenings on their walls and function as the endothecium (Fig. 9). The middle wall layer becomes crushed in fully developed anthers.

The primary archesporial cells divide mitotically in all directions and form a mass of sporogenous tissue (Fig. 2). At about the time meiosis is initiated in the pollen mother cells the nuclei of the tapetal cells divide twice mitotically and eventually become four-nucleate (Fig. 3). The tapetum is of the secretory type. The pollen mother cells divide in a successive manner and cytokinesis takes place by cell plate formation. 'T '-shaped, Deccussate and Isobilateral pollen tetrads are formed (Figs. 4, 5 and 6). The pollen grains are two-celled at the time of shedding and they contain plenty of starch (Fig. 8). The exine is smooth and the pollen grains have a single germinal furrow.

In the mature anther the two thecæ of each anther lobe coalesce ultimately and the anther dehisces by the formation of a stomium along the longitudinal edge of the union of the two thecæ (Fig. 9).



TEXT-FIGS. 1–11

TEXT-FIGS. 1–11. FIGS. 1–9. *Asparagus racemosus* Willd. Stages in the development of anther and pollen. Fig. 1. T.S. of a half anther showing two primary archesporial cells in two lobes one of which is in division, ×850. Fig. 2. T.S. of an anther lobe showing three wall layers under the epidermis, the innermost of which is differentiated into the tepetum. The sporogenous cells have increased in number and are at the pachytene stage of meiosis, ×635. Fig. 3. Shows a four-nucleate tapetal cell, ×850. Figs. 4, 5 & 6. Show 'T'-shaped, Deccussate and Isobilateral pollen tetrads, ×850. Fig. 7. Surface view of a pollen grain showing the exine with germinal furrow, × 850. Fig. 8. Shows the two-celled pollen grain in sectional view, ×850. Fig. 9. T.S. of a mature anther lobe showing the epidermis, the fibrous endothecium and the two-nucleate pollen grains, ×71. FIGS. 10–11. *Asparagus plumosus* Baker. Stages in the degeneration of the anther. Fig. 10. T.S. of an anther lobe showing a late stage of degeneration of the anther. Dark staining masses represent the pollen mother cells. The layer of wall cells which should develop into the tapetum hypertrophies, ×560. Fig. 11. Shows a dishevelled anther. ×71.

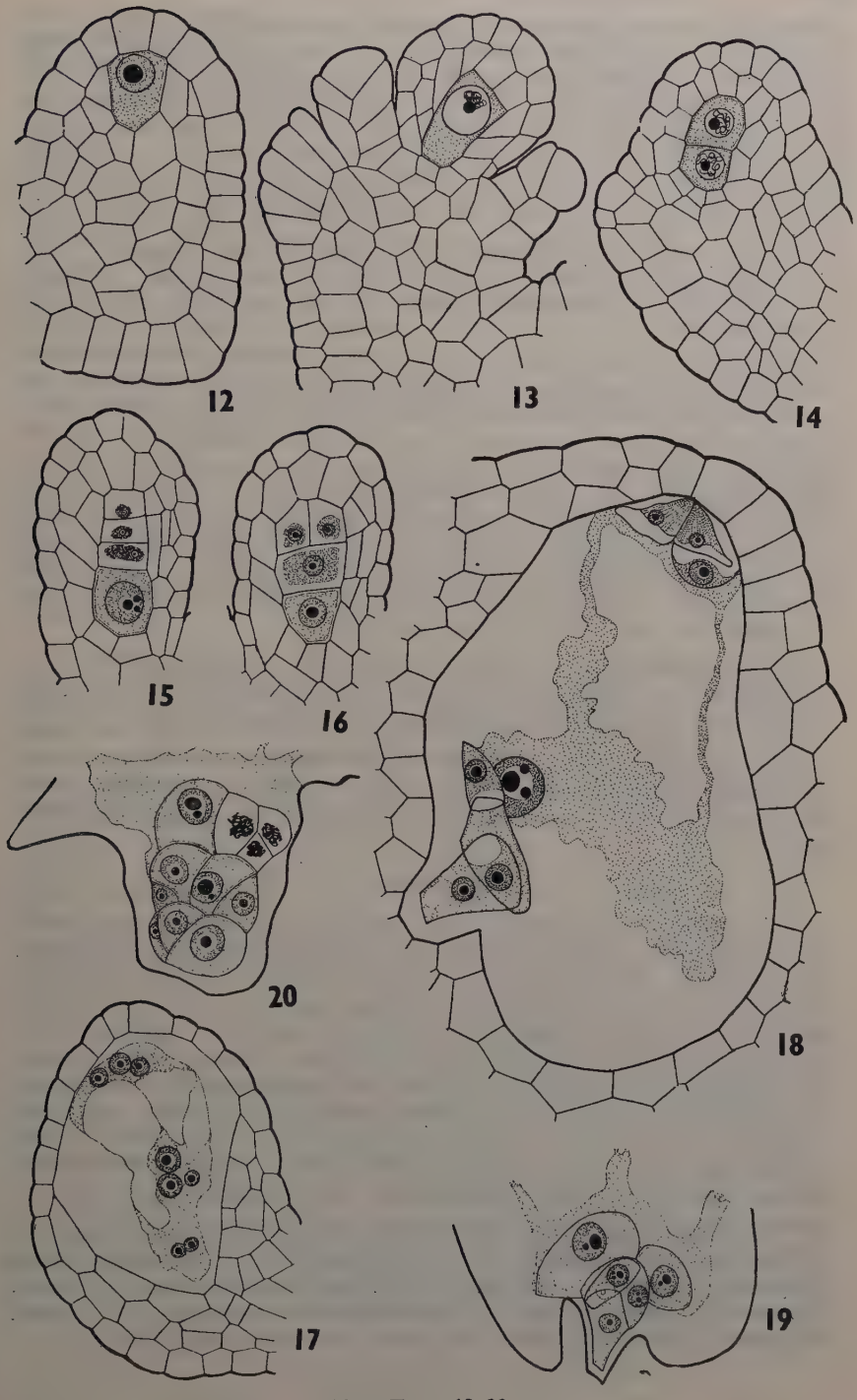
In *A. plumosus* the anthers degenerate completely before the pollen mother cells complete their meiotic division. The degeneration starts with the pollen mother cells when they are at the prophase stage and extends in a basipetal manner to all the tissues outside them and finally involve the whole anther (Figs. 10 and 11).

Megasporogenesis and female gametophyte

The ovary is superior, tricarpellary, syncarpous and trilocular with the ovules borne in two rows on axile placentation in each loculus. There are two to three ovules in each loculus. The ovules are anatropous, crassinucellate and bitegmic.

In young ovules the integuments make their appearance just at the time when the archesporial cell cuts off a parietal cell (Fig. 13). The inner integument grows more rapidly and the micropyle is formed by it alone.

The archesporium of the ovule consists of a single hypodermal cell which differentiates much before the primordia for the integuments become visible (Fig. 12). It cuts off a parietal cell to the outside and becomes the megaspore mother cell (Fig. 13). In *A. sprengeri* and *A. racemosus* ovules showing more than one megaspore mother cell have also been met with (Fig. 14). The nucellar cells on either side of the megaspore mother cell divide periclinally and form a two to three cell thick parietal tissues (Figs. 15 and 16). The megaspore mother cell undergoes the two meiotic divisions giving rise to the megaspore tetrad. Both linear and 'T'-shaped megaspore tetrads have been met with (Figs. 15 and 16). The three micropylar megaspores of the tetrad degenerate while the chalazal one enlarges in size and forms the one-nucleate embryo-sac. Three successive free nuclear divisions take place in it and an eight-nucleate embryo-sac is ultimately formed (Fig. 17). It grows considerably in size and shows a strong curvature on the side away from the funicle due to a more rapid growth on that side, resulting in the formation of a cæcum or diverticulum which functions as a haustorial organ (Fig. 18). The ovule also undergoes a considerable increase in size.



TEXT-FIGS. 12–20

TEXT-FIGS. 12–20. FIGS. 12–16. *Asparagus racemosus* Willd. Stages in the development of ovule and embryo-sac. Fig. 12. L.S. of an young ovule showing the hypodermal archesporial cell, ×653. Fig. 13. L.S. of an ovule showing the megaspore mother cell at the synigisis, two parietal cells and the initials of the integuments being formed, ×653. Fig. 14. L.S. of an young ovule showing two megaspore mother cells, ×653. Fig. 15. L.S. of an ovule showing the linear megaspore tetrad, ×653. Fig. 16. L.S. of an ovule showing a 'T'-shaped megaspore tetrad, ×653. FIGS. 17–18. *Asparagus sprengeri* Regl. Fig. 17. L.S. of an ovule showing the eight-nucleate unorganized embryo-sac in which the polar nuclei have migrated to the centre, they are of a larger size than the rest of the nuclei, ×653. Fig. 18. L.S. of an ovule showing a well developed diverticulum in mature embryo-sac. Note the lateral position of the antipodals. ×655, FIGS. 19–20. *Asparagus plumosus* Baker. Fig. 19. Shows six antipodal cells, ×560. Fig. 20. Shows eleven antipodal cells out of which three are degenerating, ×560.

The mature embryo-sac contains the egg apparatus, the antipodals and the secondary nucleus. The egg apparatus is situated below the micropyle and consists of the egg with an apical vacuole and a nucleus in the basal lining of cytoplasm (Fig. 18). The synergids are hooked and show basal vacuoles. A filiform apparatus is differentiated in their apices (Fig. 18). Due to the unequal growth of the embryo-sac the antipodals in the mature embryo-sac come to lie on the side away from the diverticulum (that is, on the side of the funicle) and at right angles to the longitudinal axis (chalazal-mycropylar) of the ovule (Fig. 18). The antipodals are large in size. They are arranged either in a superposed or in a 'T'-shaped manner.

The antipodals of *A. plumosus* undergo a secondary increase in their number by mitotic divisions. As many as eleven cells have been noted in one case (Fig. 20), six being quite common (Fig. 19).

The post-fertilization stages of the development of the ovule and development of the endosperm and embryo could not be studied as the seed set in the species investigated is extremely poor or even practically nil.

DISCUSSION

The archesporium of the young anther consists of a single row of hypodermal cells. Three wall layers are developed below the epidermis. The innermost wall layer develops into a secretory tapetum and the sub-epidermal layer into the fibrous endothecium. The middle layer gets crushed. Pollen mother cells divide in a successive manner forming Isobilateral, Deccussate and 'T'-shaped tetrads. The mature pollen grains are two-celled at the time of shedding and show a single germinal furrow. This is a constant feature of the family except in a few plants like *Tulipa gesneriana*, *Polygonatum multiflorum*, *Lilium tigrinum* and *Yucca recurva* (see Schnarf, 1931), where three nucleate pollen grains occur. In *A. plumosus* the anther degenerates totally.

The ovule is anatropous, crassinucellate and bitegmic and the micropyle is formed by the inner integument alone in *Asparagus* as in many other Liliaceæ. In the subfamilies Allioideæ and Lilioideæ, however, the ovule borders on a tenuinucellate condition and a third integument is formed in the form of an aril (see Schnarf, 1931).

The female archesporium consists of a single hypodermal cell which cuts off a parietal cell in all the species. Parietal cell formation is, however, not a constant feature in this family. For instance, a large number of genera show the formation of a parietal cell (see Schnarf, 1931) while in plants like *Gloriosa* (Eunus, 1949), *Tulipa maximovica* (Romanov, 1939), *Clintonia borealis* (Smith, 1943) no parietal cell formation is seen and Dahlgren (1927) gives a list of plants in which a parietal cell is formed in some ovules and not formed in others.

The embryo-sac development is according to the Polygonum type in all the four species of *Asparagus* investigated in the present study. In the tribe Asparagæ no other type of embryo-sac development has so far been recorded, while in the rest of the three tribes, Polygonatæ, Convallarieæ and Parideæ other types of embryo-sac development are on record. In Polygonatæ, Polygonum, Allium and Drusa types occur. In Convallarieæ, Polygonum and Allium types occur while in the Parideæ only the Allium type is on record.

A conspicuous embryo-sac diverticulum develops in all the species and it functions as a haustorium. Such an embryo-sac diverticulum has not been previously reported in the subfamily Asparagoideæ. However, it has been recorded in *Veltheimia*, *Anthericum*, *Arthropodium*, *Allium* and *Yucca* which belong to other subfamilies of Liliaceæ (see Schnarf, 1931).

The egg apparatus and the antipodals show a typical structure in all the species. In *A. plumosus*, however, sometimes the antipodals undergo a secondary increase in their number. As many as eleven cells have been noted in one case. Occurrence of many antipodal cells is not uncommon in this family and has been previously recorded in *Lilium tigrinum* (see Schnarf, 1931) and *Trillium undulatum* (Swamy, 1947). In *Allium odorum* (see Schnarf, 1931) and *Trillium undulatum* (Swamy, 1947) the antipodals divide and form embryos. Multinucleate antipodals have been recorded in *Veratrum album*, *Zygadenus elegans* (cited by Schnarf, 1931) and *Drimiopsis kirki* (Sundara Rao, 1940).

Sterility and consequent poor or no fruit formation and seed set are widespread phenomena within the various species of *Asparagus*.

Summary

Microsporogenesis and male gametophyte and megasporogenesis and female gametophyte have been studied in *Asparagus* in *racemosus* Willd., *A. officinalis* L., *A. sprengeri* Regl., and *A. plumosus* Baker.

Microsporogenesis and male gametophyte

The anther shows a wall consisting of three layers under the epidermis. The hypodermal wall layer develops into the fibrous endothecium and the innermost into the secretory tapetum. The tapetal cells become two to four-nucleate. Pollen mother cells divide in a successive manner. 'T'-shaped, Isobilateral and Deccussate pollen tetrads have been met with. The pollen grains are two-celled at the time of shedding

and contain abundant starch. Exine is smooth and has a germinal furrow. In *A. plumosus* the anthers degenerate totally and the degeneration usually begins at about the time when meiosis sets in the nuclei of the pollen mother cells.

Megasporogenesis and female gametophyte

The ovules are anatropous, bitegmic and crassinucellate. The micropyle is formed by the inner integument alone. The primary archesporium in the ovule consists of a single hypodermal cell. A parietal cell is cut off. Both 'T'shaped as well as linear megaspore tetrads have been met with. Am embryo-sac diverticulum develops on the side away from the funicle due to an unequal growth of the embryo-sac and functions as a haustorium. The antipodals are pushed to a side and come to lie in a position at right angles to the longitudinal axis of the ovule (chalazal-micropylar). The egg apparatus cells show normal structure. The synergids are hooked and show a filiform apparatus at their apical parts.

ACKNOWLEDGEMENTS

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STUDIES IN INDIAN SAUTERIACEÆ

I. Sporeling Patterns in *Athalamia pinguis* Falc.*

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(Received for publication on February 3, 1958)

Introduction

In a recent classification of the hepatics Evans (1939) assigned four genera to the Sauteriaceæ, *viz.*, *Clevea* Lindbg., *Peltolepis* Lindbg., *Sauchia* Kash. and *Sauteria* Nees. Of these *Clevea* has recently been shown by Shimizu and Hattori (1954) to be generically not distinct from *Athalamia* Falc. and they united the genera *Athalamia* Falc. (Falconer in *Trans. Linn. Soc.* **20**: 397, 1851) and *Clevea* Lindbg. (Lindberg in *Not. Sællsk. Fauna et Fl. Fenn.* **9**: 289, 1868) into one. In an earlier communication Kashyap (1929) had already reduced *Gollaniella* St. (Stephani in *Hedwigia*, **64**: 74, 1905) to a synonym of *Athalamia*. The latter being the oldest of the three genera has been retained.

Considered in the above over-all revised context the genus *Athalamia* now embraces 14 species including a recently described species, *A. glauco-virens* Shim. *et* Hatt. (*see* Shimizu and Hattori, 1954; Hattori and Shimizu, 1955). In India *Athalamia* is represented by three species, *viz.*, *A. pinguis* Falc., *A. dioica* Kash. and *A. pusilla* (St.) Kash. In segregating *A. dioica* as a new species Kashyap (1929), however, remarked that this species is doubtfully distinct from *A. pinguis*.

Peltolepis Lindbg. is a rare genus and was for a long time represented by a single species, *P. quadrata* (Sauter) K. Müll., growing largely in the Northern Hemisphere. Recently, however, a new species, *P. japonica* (Shim. *et* Hatt.) Hatt., has been added. This species is so far known to be restricted to an isolated locality at Mt. Yatsu (2,250–2,450 m. alt.), Central Japan (*see* Hattori and Shimizu, 1955). The genus *Peltolepis* yet awaits discovery in India.

The monotypic endemic genus *Sauchia* Kash., from the Western Himalayas, has been shown by Shimizu and Hattori (1954) to be identical with *Sauteria* Nees. Judged from this synonymy the genus *Sauteria* is represented by six species including *S. yatsuensis* Hatt., recently described by Hattori and Shimizu (1955), from Mt. Yatsu, Central Japan.

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Of these species, *S. alpina* Nees and *S. spongiosa* (Kash.) Hatt. occur in India. In discussing the status of *Sauchia spongiosa* Kash., Hattori and Shimizu (1955) remarked that the Indian "*S. spongiosa* is known only by literature, and a comparative study based on its original material is much desired". The status of *Sauchia spongiosa* Kash., therefore, still remains an open question and needs careful study as this is an endemic genus in our flora.

Distribution of the Sauteriaceæ in India

Sauteriaceæ thus, as at present understood, are represented by three genera, *viz.*, *Athalamia* Falc., *Peltolepis* Lindbg. and *Sauteria* Nees of which *Athalamia* and *Sauteria* occur in India showing a very restricted distribution as detailed below:—

Name of the Plant	Distribution
1. *Athalamia pinguis* ..	On exposed slopes. Very common in the outer and Kumaun Himalayas, 5,008–8,000 ft. Mussoorie, Simla, Kulu, Ravi Valley, etc. (Kashyap, 1929).
2. *A. dioica* ..	On roadside. Pangi, about 7,000 ft. between Kilar and Sauch. (Kashyap, 1929).
3. *A. pusilla* ..	Moist and shady places. Common in the outer and Kumaun Himalayas, 6,000–10,000 ft. Simla; Kulu, Dulchi Pass; Lahul, Kyelang; Mussoorie, Joshi Math, etc., Kashyap (1929).
4. *Sauteria alpina* ..	Kashmir, Liddar valley, 13,000 ft. (Duthie) (Stephani, 1900).
5. *S. spongiosa* ..	On moist shady rocks or actually under cold flowing water. Middle and Main Himalayas 9,000–14,500 ft. Above Alwas on the Pangi Road, 9,000 ft.; both sides and top of Rotang Pass, 13,400 ft.; beyond Baralacha Pass, 14,500 ft.; Chandra Valley, Manh Pass (Kashyap, 1929).

It would be clear from the table above that these plants are rather rare in India and, therefore, stand in need of careful investigation not only in view of our relatively very meagre knowledge of their taxonomic and morphological details but also due to the recent concepts involved with respect to the status of some of these.

At the kind suggestion of Dr. S. K. Pandé, the author, therefore, intends to pursue a somewhat detailed investigation covering taxonomy, morphological and developmental details and cytology of the members of this group. The present investigation deals with

the sporeling patterns of *Athalamia pinguis*. No compact published accounts, on this interesting aspect of the genera of the Sauteriaceæ, have so far been presented.

Material and Methods

Athalamia pinguis has repeatedly been collected by Dr. Pandé during the last several years and excellent collections are represented for morphological investigations. The specimens for the present communication were collected by the author from Mussoorie at the Camel's Back Road (alt. 6,000–7,000 ft.) during the last week of September and the first week of October 1957. This is the time when the plants normally complete their life-cycle and show dehisced capsules or intact capsules with mature spores.

A. pinguis is curiously pocketed in restricted areas and grows on thin soil over the exposed calcareous sandstones associated with such xeromorphic species as *Plagiochasma appendiculatum* L. *et* L., *Asterella angusta* (St.) Kachroo and *Targionia hypophylla* L.

The spores of *A. pinguis* are perfectly black and opaque at maturity (Text-Fig. 1), 65–70 μ being the maximum diameter, tetrahedral, reticulate with 6–8 reticulations across the outer face and with surface warty (Text-Figs. 2, 3). Complete mature sporophytes were isolated from the receptacle and the spores cultured on October 14, 1957 in the laboratory at room temperature in sterilized covered Pyrex glass Petri dishes containing:—

(1) sterilized tap water,

(2) sterilized soil extract from the soil obtained from the home locality of the plant,

(3) sterilized full strength and half strength Knop's solution,

(4) 2% Bacto-agar, and

(5) sterilized moist soil.

The usual constituents were utilized for making Knop's solution.

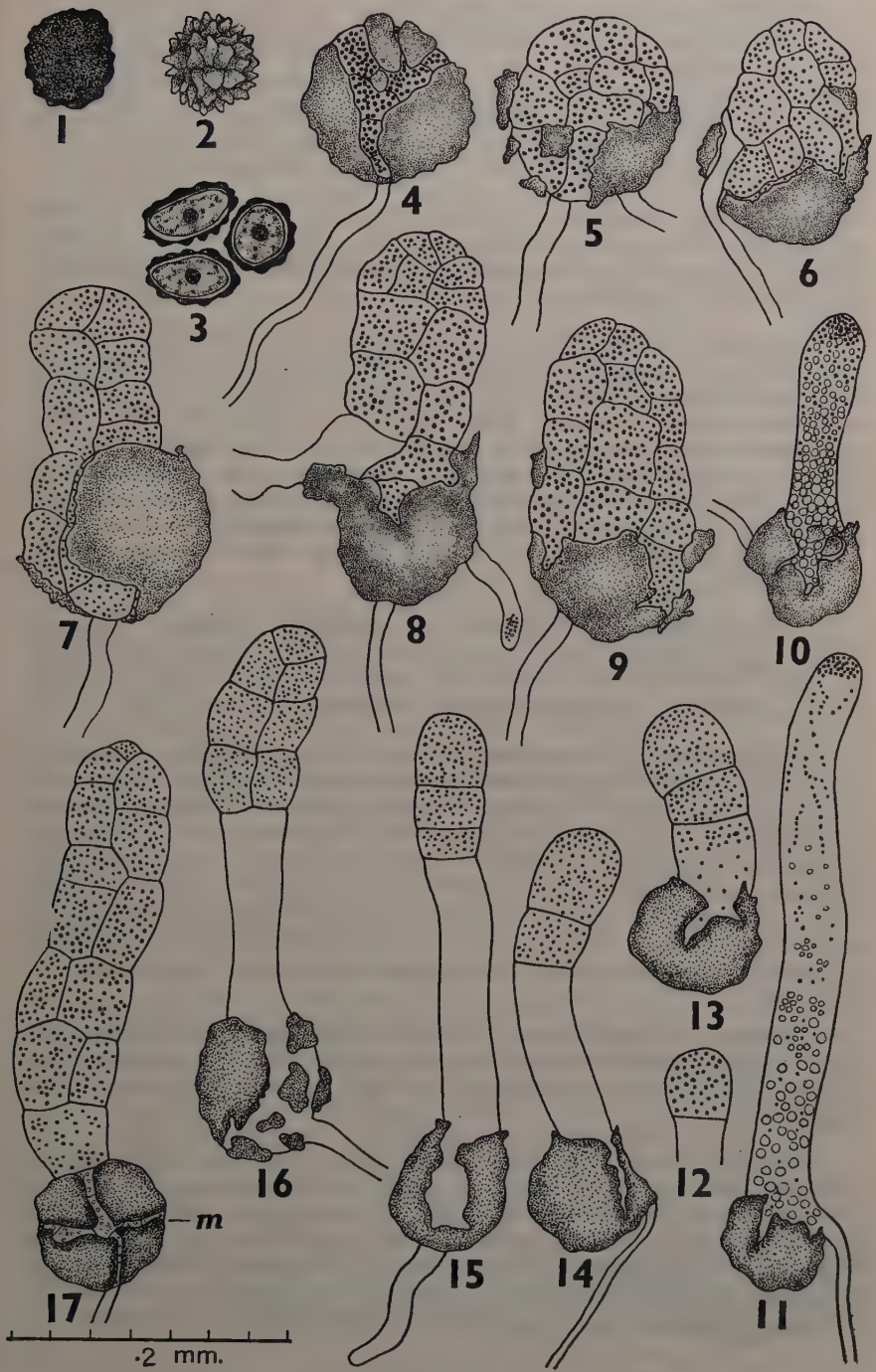
The cultures received diffused sunlight through the North glass window panes of the laboratory.

The spores germinated in all these cases except in (4). Best growth was observed in (2), (3) and (5) although the first two had the disadvantage of getting contaminated with algal and fungal growths. These contaminants, however, interfered when most of the early sporeling stages had been obtained. In (5) the sporelings continued to grow till two months after culture and developed into somewhat mature gametophytes.

Observations

Sporeling Germination

In culture the spores of *A. pinguis* apparently do not require a rest period as those collected on October 6, 1957 and cultured on



TEXT-FIGS. 1–17

TEXT-FIGS. 1–17. Fig. 1. A mature spore. Fig. 2. A young spore showing surface outgrowths. Fig. 3. Section through spore tetrad. Fig. 4. Rupture of the spore coat at the tri-radiate mark. Note the enormous swelling of the spore and a conspicuous elongated rhizoid. Figs. 5–9. Growth of the multicellular germ disc. Note differences in the number and position of the rhizoids. Fig. 10. Emergence of the germ papilla laden with food materials (Soil culture). Fig. 11. Elongation of the germ tube. Note the position of the first rhizoid. Figs. 12–15. Early cell divisions. Fig. 16. A young germling showing the two-sided apical cell. Fig. 17. A young germling from soil culture. *m*, degenerated multicellular germ disc.

October 14, 1957 germinated in about five days. The viability of these spores was in the neighbourhood of 75%. Close observations have indicated that there is a great deal of diversity in developmental stages exhibited by the sporelings of *A. pinguis*.

In a large number of cases the early stages of germination proceed while the spore coat is apparently still intact, the only obvious sign being the enormous swelling of the spores. Finally the spore coat ruptures along the tri-radiate mark, due to the pressure of the dividing cells within, and usually it is the rhizoid which emerges first and elongates considerably (Text-Fig. 4). Continued cell divisions result in the formation of a multicellular germ disc which is now exposed by the spore coat getting torn off in isolated shreds (Text-Figs. 5–9). Stages as these would, however, wrongly suggest of an irregular rupture of the spore coat.

The position of the rhoizoids is extremely variable. Whereas some stages strongly point to a distinct polarity (Text-Figs. 4, 7, 9), in others differences in position and number of the rhizoids preclude the possibility of any fixed polarity (Text-Figs. 5, 6, 8, 19, 21, 24).

The multicellular germ disc, under normal conditions, invariably passes impercept.bly into the young gametophyte (Plate XVIII, Figs. 1–3) and the early growth (Text-Figs. 5–9) is definitely controlled by the establishment of a two-sided apical cell (Text-Figs. 7–9). Later on, at the apical region the marginal cells divide rapidly resulting in its expansion and formation of a notch at the apex (Plate XVIII, Figs. 1, 2) which subsequently encloses the usual group of initials found in the adult gametophyte. Under excessive moisture the germ disc continues its growth to form a cylindrical elongated column of cells (Plate I, Fig. 3).

Although the development of a single multicellular disc is a normal feature, quite often there is an early bifurcation of the germ disc (Plate XVIII, Figs. 7, 8). In these cases both the branches may develop into normal thalli.

The formation of a multicellular germ disc is, however, not a constant feature. Occasionally a germ tube emerges through the ruptured spore coat (Text-Fig. 10) laden with food materials. The germ tube may elongate to a certain degree (Text-Fig. 11), before divisions are laid down. In such cases it is quite obvious that the enormous swelling of the spores, noticed in the formation of the multicellular germ disc, is not realized. The chloroplasts accumulate at

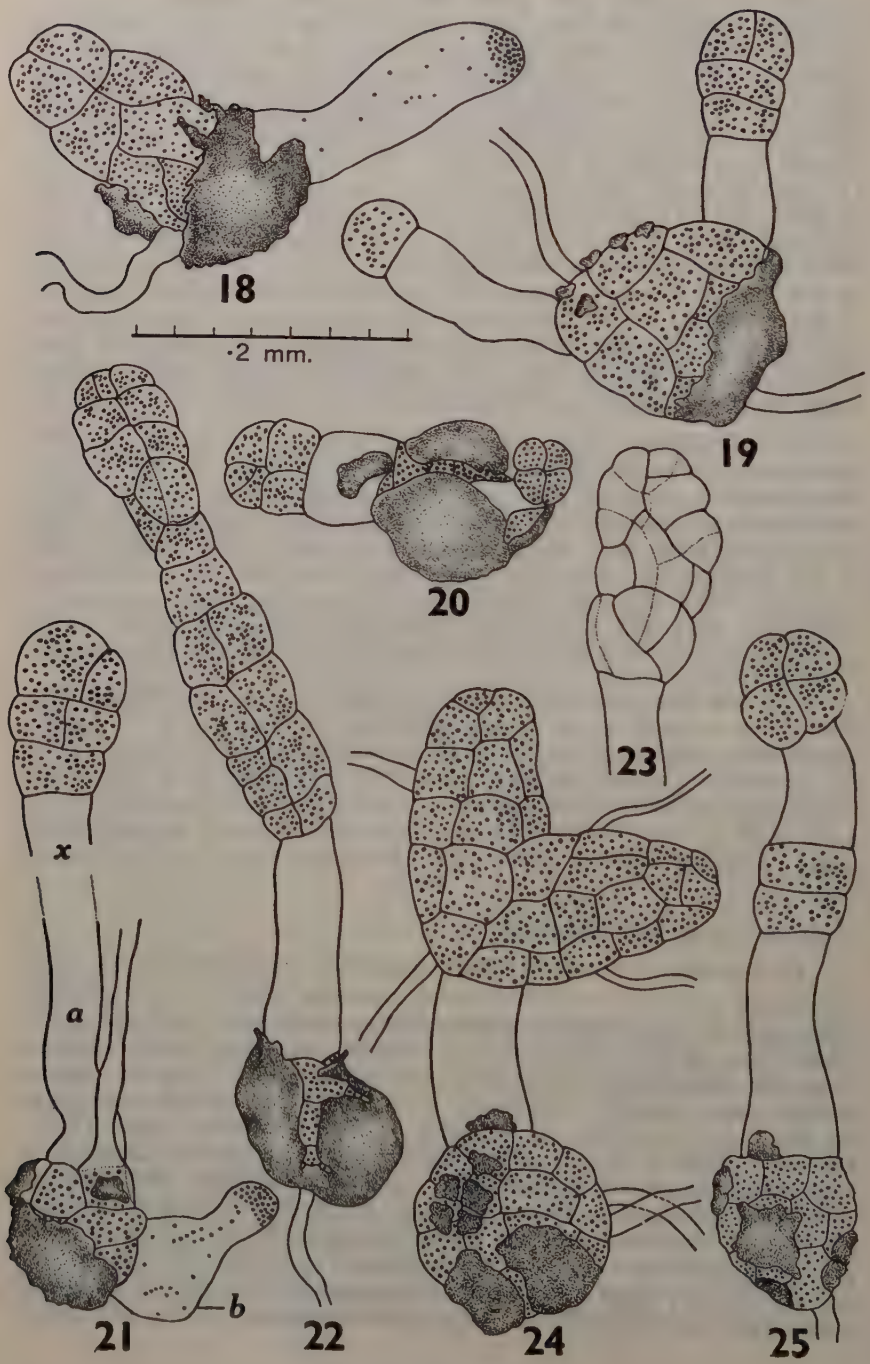
the apex of the germ tube where the latter bulges conspicuously. A transverse septum near the bulge separates the first cell of the germ disc (Text-Fig. 12). This cell may repeat similar divisions once or twice (Text-Figs. 13–15) and finally vertical divisions set in (Text-Fig. 16). Quite early in development a two-sided apical cell is established (Text-Fig. 16) which contributes to the formation of a multicellular column in continuation of the germ tube (Plate XVIII, Figs. 4, 5). The variability in the position of the rhizoids is also clearly noticed in these cases (Text-Figs. 10, 11, 14–16). An interesting case is the one represented by Text-Fig. 11. It is very suggestive of the formation of the first rhizoid as in *Riccia* (Udar, 1957*a*; 1957*b*). In fact the sequence of divisions in the early stages of the sporelings also largely correspond to *Riccia* except for the rupture of the spore coat at later stages in several isolated small shreds and the emergence of the germ tube through the tri-radiate mark. The ultimate irregular rupture of the spore coat is apparently a constant feature in *A. pinguis*.

In soil cultures the formation of a germ tube in the sporeling development is rather pronounced. In several cases, however, a distinct multicellular germ disc is definitely organized but, as the spores are somewhat embedded in the soil, outgrowths develop from this disc and organize at their apices multicellular discs. The original cells of the multicellular germ disc get disorganized and lose chloroplasts (Text-Fig. 17). This certainly is due to inadequate light received by such germ discs and outgrowths from them are merely a device for securing requisite conditions for further growth into the gametophyte.

It would thus be evident that the formation of a multicellular germ disc is the normal course in the sporeling development in *A. pinguis* which would definitely be extremely advantageous as the plants grow in perfectly exposed habitats and the formation of a germ tube would apparently be a disadvantage. However, the formation of a germ tube or secondarily formed tubes only represent an adaptation under abnormal culture conditions. The latter has been discussed below.

Regeneration in the Sporelings

In crowded cultures or those which get contaminated by algal and fungal growths or those receiving excessive moisture or insufficient light, copious regeneration potentiality is exhibited by the sporelings (Text-Figs. 18–25). Often one to several secondary tubes develop from the multicellular germ disc and these usually repeat almost similar stages, towards organizing a disc, as in the sporelings develop ing after the formation of a germ tube. In some cases (Text-Fig. 25; Plate XVIII, Fig. 6) unsuccessful attempts to organize a disc brings about the formation of curious structures. Referring to such behaviours under culture conditions Dr. S. K. Pandé, in his learned Presidential Address before the Indian Botanical Society meeting, 1958, ably remarked that they merely represent regeneration phenomenon and the primary germ disc in no way represents a protonema while the outgrowths from this disc are simply the regenerants which later grow



TEXT-FIGS. 18–25

TEXT-FIGS. 18–25. Figs. 18–20. Multicellular germ disc showing regenerants in several stages of development. Fig. 21. Regenerant (*a*) with a very long tube (broken at *x* and full length not shown) and an initial stage of another regenerant (*b*). Fig. 22. Elongated multicellular regenerant from water culture. Fig. 23. A multicellular regenerant 2–3 layers thick. Fig. 24. Early branching of a regenerant. Fig. 25. Successive regeneration showing unsuccessful attempts to organize a disc.

and organize normal gametophytes after reaching suitable conditions for growth (Pandé, 1958).

The growth of the regenerants in early stages is controlled by a two-sided apical cell (Text-Fig. 23) which, at later stages, is replaced by the usual group of initials of the adult gametophyte much in the same way as in the sporelings. In some cases the regenerants show early dichotomy (Text-Fig. 24) as noticed in the sporelings (Plate XVIII, Figs. 7, 8). Occasionally the tube subtending a regenerant may elongate considerably (Text-Fig. 21) and quite often the regenerant may grow into a cylindrical elongated structure (Text-Fig. 22).

SUMMARY

1. The sporeling germination in *Athalamia pinguis* Falc. has been described.

2. The specimens bearing mature sporophytes were collected by the author from Mussoorie during September-October 1957.

3. In culture the spores of *A. pinguis* apparently have no rest period as those collected on October 6, 1957 and cultured on October 14, 1957 germinated in about 5 days.

4. The viability of the spores is in the neighbourhood of 75%.

5. The early stages in the sporeling development show a great deal of variations in culture.

6. Normally a multicellular germ disc is organized while the spore coat is still intact. Due to pressure of these dividing cells the spore coat ruptures at the tri-radiate mark and the first conspicuous structure to emerge is usually a rhizoid which elongates considerably. Subsequently the germ disc is exposed by the irregular rupture of the spore coat in isolated shreds.

7. Occasionally a germ tube is formed instead of a germ disc. In such cases the enormous swelling of the spores, as in the development of the multicellular germ disc, is evidently not realized. Later a multicellular disc is organized in continuation of the germ tube as in *Riccia*.

8. There is no fixed polarity in the development of the rhizoids and the germ tubes or germ discs. In some cases the first rhizoid arose as a continuation of the germ tube as in *Riccia*.

9. The multicellular germ disc passes imperceptibly into the adult gametophyte. Early growth of the germling is controlled by a

two-sided apical cell which is later replaced by the usual group of initials characteristic of the adult gametophyte.

10. Under abnormal culture conditions copious regeneration potentiality is exhibited by the sporelings.

ACKNOWLEDGEMENTS

Grateful thanks are due to Dr. S. K. Pandé, D.Sc., for his keen interest and valuable guidance in the preparation of this paper.

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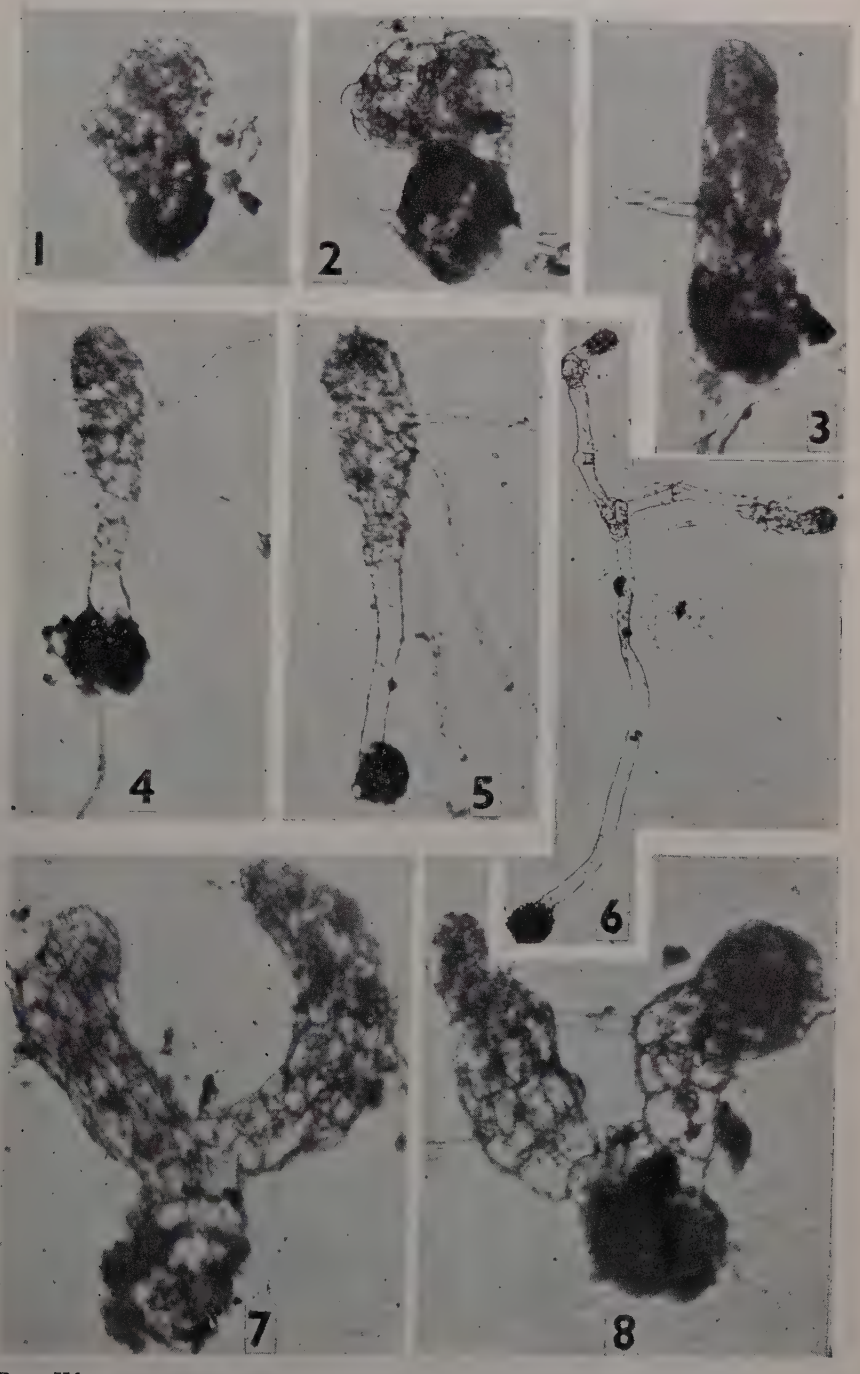
EXPLANATION OF PLATE XVIII

FIGS. 1–3. Multicellular germ discs, ×70.

FIGS. 4–5. Germlings subtended on germ tubes, ×50.

FIG. 6. Regeneration (from crowded culture), ×50. Note the peculiar structure developed revealing several unsuccessful attempts at organizing a disc.

FIGS. 7–8. Early branching in germlings, ×100.



Ram Udar

A PRELIMINARY SURVEY OF THE SAND-DUNE VEGETATION OF PILANI AND ITS NEIGHBOURHOOD

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Introduction

It is only in recent years that the Rajasthan desert has drawn the attention of the Indian botanists. King was the first to give an account of the Indian desert in 1879. He published a "Sketch of the Flora of Rajputana". This was followed by a much more detailed work by Blatter and Hallberg (1918–21). Afterwards it was only recently that a few papers of taxonomic interest were published. Mulay and Ratnam (1950), Ramachandran (1950), Das and Sarup (1951), Ratnam (1951), Sankhala (1951), Sarup (1951), Bakshi (1954), Nair (1956), and Nair and Nathawat (1956) published lists of plants growing in this region.

A few more papers regarding the ecological and morphological aspects of vegetation were published by Krishnaswamy and Gupta (1952), Ratnam and Joshi (1952), Sarup (1952), Bakshi and Chhajlani (1953), Bakshi and Kapil (1952, 1954), Nair (1954) and Joshi (1956, 1957). In a recent publication on the Rajputana desert by the National Institute of Sciences of India, several authors like Agharkar (1952), Biswas (1952), Puri (1952), and Sarup (1952) have contributed to the ecology and vegetation of the Indian desert.

A survey of the above literature shows that the eastern part of the Indian desert has been so far sadly neglected. Apart from the sketchy accounts of the trees and shrubs of important cities like Jaipur and Alwar as given by the Forest Officers and some papers on the vegetation of this part of the desert in references quoted above, Nair and Joshi (1955) presented a short paper "On the Sand-Dune Vegetation of Pilani and its Neighbourhood" at the Symposium on the Vegetation Types of India, held at Baroda.

The main purpose of this paper is to give an account of the preliminary survey of the sand-dune vegetation of Pilani and its neighbourhood in the Shekhawati region of Rajasthan, carried out within th past four years. The present study is being pursued with Birla Colleg Pilani, as the centre. A detailed investigation is in progress.

Location and Topography

Pilani is situated a little over a hundred and seventy-seven kilometres to the west of Delhi and is in the north-western part of Jhunjhunu District in the Jaipur Division of Rajasthan. The place has attained great importance recently since many institutions have sprung up within the span of a few years. The Birla College, situated in Vidya Vihar, is one of the institutions located in the new educational colony. Taking this as centre the study is being conducted in the neighbouring areas covering approximately 16 kilometres or so all around. The important roads, tracks and villages within the area are shown in the map (Text-Fig. 1).

The only river of importance in the area is river Katli. This and a few other minor streams contain some water during the rainy season, as they are soon lost into the sands within the outlines of Jhunjhunu and Sikar Districts in the Shekhawati region. Whenever there is a heavier rainfall the river Katli flows a little farther. Thus the area is almost devoid of free running water, the only perennial source of water being the wells. The water-table in the area is usually 32 to 40 metres deep.

The terrain is not altogether flat as there are isolated outcrops of rock in the area surveyed and all over Shekhawati. The land can be classified into the following categories:—

1. *Loamy Hard Soil Areas*

There are small as well as big patches of land interspersed in the sandy plains of the area surveyed. The soil is usually hard and loamy. Such areas are very few in number but wherever they are present, they are clothed with thick vegetation. They usually support extensive stands of either *Capparis* or *Zizyphus* or *Salvadora*, the first being more common. These are the only places where rain-water is held due to higher retentive capacity of the soil. In the low-lying areas of the loamy hard soil temporary ponds are often formed.

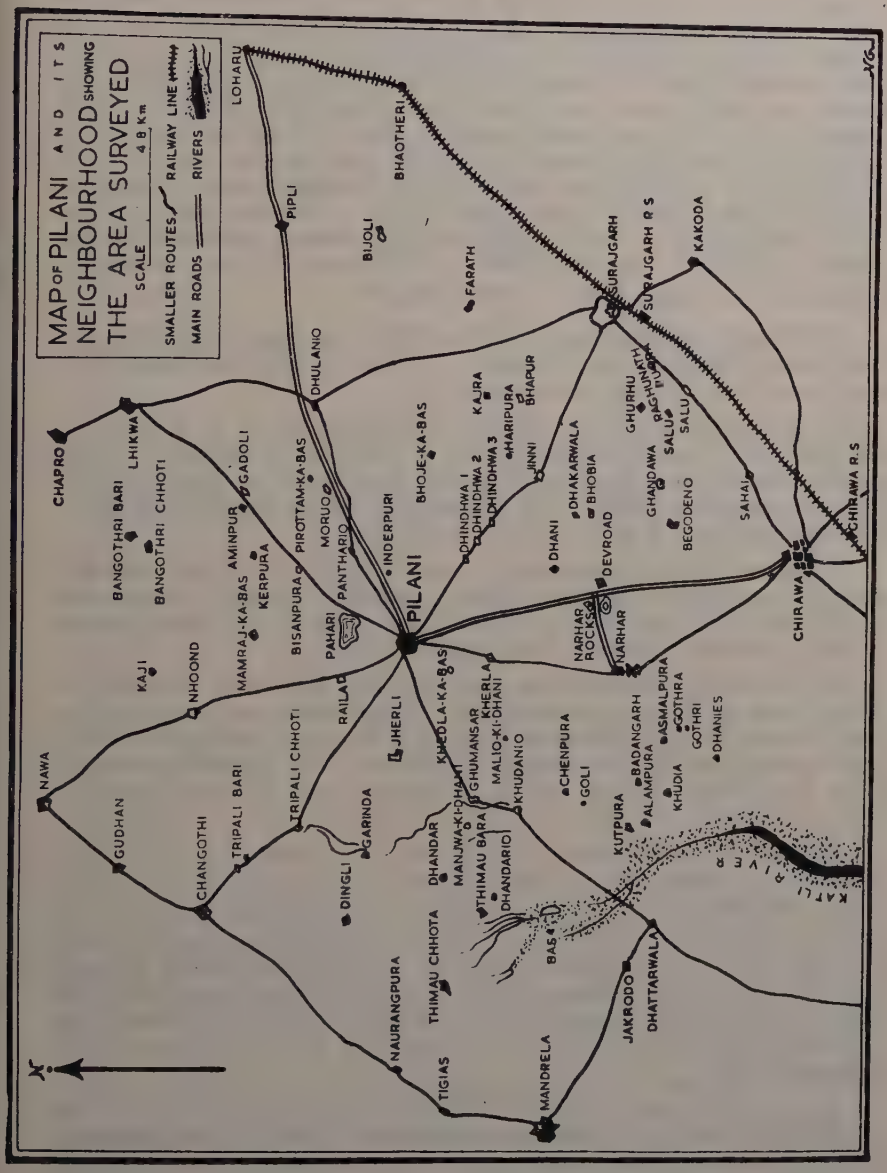
2. *Sandy Plain Areas*

The vast area of the land covered by sandy plains is made up of loose soil which is subject to rapid erosion. After adding manure to the soil this land is mostly used for cultivation of rainy-season crops.

3. *Sand-Dune Areas*

The area under investigation possesses a large number of sand-dunes. A point of interest is that sand-dunes, wherever they are formed, are aggregated in quite large numbers. But in all cases the direction of the dune corresponds more or less with that of the prevailing winds. The following types of sand-dunes have been recognised in the area surveyed:

(*a*) *Embryonic Dunes.*—These dunes are produced by the action of the wind which brings the sand and deposits it in small heaps at a



TEXT-FIG. 1. Map of Pilani showing area surveyed

few scattered places. Changes in size and shape are brought about by the direction and velocity of the wind. The embryonic dunes gradually fuse together and become bigger.

(*b*) *Barchanoid Dunes*.—Bakshi (1954) has reported the existence of such types of dunes in Pilani and its neighbourhood. According

to Bagnold (1941) the Barchanoid dune type can occur only when the wind is nearly unidirectional. But in the area investigated the wind is not always unidirectional, crosswinds being common. During winter when the wind is nearly unidirectional typical Barchanoid dunes may be met with. But these change their shape with the onset of the summer, when the cross winds begin to blow. Thus, the Barchanoid type is found distorted; the arms of the Barchan may be partly or completely lost, or one arm may become longer than the other—resembling a sickle, or upon fusion of Barchanoid dunes, a parabola results. The typical Barchanoid or ' sickle '-shaped dunes always have their slopes towards the east, or north-east, while in the distorted forms, there is no constancy, since they undergo many changes.

Sometimes the Barchans fuse together in an aggregated form and thus create a stage for stabilization. In the present study these have been named as " Fusing Barchanoids ".

(*c*) *Longitudinal or Seif Dunes.*—The presence of such dunes is also quite common at certain places in the area investigated. They are found scattered in long ridges but are never found in parallel chains. They are generally stable. The direction of these longitudinal dunes is either from west to east or south to north.

(*d*) *Sand Mounds.*—Scattered sand mounds have been located within the area surveyed. They develop around obstacles to the moving sand grains which are trapped there. The roots of the plants present on these mounds consolidate and bind the sand.

(*e*) *Stabilized Dunes.*—This type of dune has been observed at many places in the area under study. These dunes are quite large in size, because they are formed as a result of fusion of embryonic dunes. They always support a luxuriant vegetation. An interesting feature about these dunes is that the space between two stabilized dunes is often very small.

In brief, the substratum of the desert tracts in Pilani and its neighbourhood has been subjected to mechanical disintegration due to extremes of temperature, high insolation and powerful winds. The winds transport enormous amounts of dust and sand for long distances and pile them against slight resistance. Accumulated heaps of sand mark out a series of ridges and dunes. A striking phenomenon of desert erosion is illustrated within the area thus giving it a worn out and sand blasted topography which has been built up within recent geological time.

Climate

Due to paucity of adequate equipment for meteorological observations in the area covered by the survey and there being no official recording station, complete climatic records are not available. Table I presents a summary of the features of the climate of the area, which is based on stray and incomplete records kept in the local Agricultural Farm and in the Department of Geography of the Birla High School, Pilani. The nearest meteorological station to Pilani is Sikar. The data collected for this place have also been shown in Table I. It may

TABLE I

Yearly Average Records of Rainfall and Temperature

(From 1950–56)

Locality	Year	Temperature in degrees C.		Rainfall in m.m.	Humidity	
		Maximum	Minimum		8–30 A.M.	5–30 P.M.
PILANI ..	1950	30·5	19·7	260·2	..	..
SIKAR ..		..	..	..	..	..
PILANI ..	1951	33·6	19·9	298·3	..	..
SIKAR ..		31·5	17·0	299·1	67·3	51·5
PILANI ..	1952	34·8	17·4	500·0	..	..
SIKAR ..		31·8	18·0	371·6	64·9	51·6
PILANI ..	1953	..	..	254·0	..	..
SIKAR ..		32·6	16·4	540·7	64·2	45·1
PILANI ..	1954	33·1	19·8	457·1	..	..
SIKAR ..		31·4	16·5	268·7	64·0	41·0
PILANI ..	1955	39·9	28·6	482·6	..	..
SIKAR ..		32·5	18·6	618·9	70·8	58·5
PILANI ..	1956	36·2	19·3	656·8	..	..
SIKAR ..		31·2	17·5	306·0	74·3	57·8

be noted that Pilani region is only semi-arid in contrast to the other parts of the Indian desert which are arid. The average rainfall varies approximately from 254 to 657 mm., most of which is received in August. Winter rains are received but in small amount. The remaining months are dry. Excepting the month of August the relative humidity is usually low. The whole area experiences extremes of temperatures. The winter is usually very cold and begins from about the middle of November and ends by the middle of March. The temperature during the cold season is generally very low, sometimes touching the freezing point. Summer is very hot, the season being very severe during April, May and June. But there is generally a great variation of temperature between day and night. Nights are usually cool and pleasant.

There is a constant breeze blowing in the area eroding the soil and transporting the sand. During the summer the prevailing scorching winds blow with great violence and sand storms are quite common.

Bakshi (1954) states: "There is a constant breeze in Pilani from the south-west to north-east from about February to October with a velocity of nearly 8–10 miles per hour. The velocity increases during May to 20 miles per hour and the direction changes to west-east. Storms of higher velocity are almost not infrequent". Unfortunately the meteorological data are very meagre and hence nothing can be said with definiteness of the velocity of the winds, there being winds and cross winds which make it all the more difficult to form an idea about the same.

Soil

The soil within the area under investigation differs considerably from locality to locality. A survey of the nature and chemistry of the soil as given in Table II shows the following important features:

1. *Cultivated Fields and Agricultural Farm Areas*

The soil is sandy, brownish black in colour and is a mixture of sand and a little silt. There is an appreciable amount of humus in the soil. It has considerable water retentive capacity. As compared to the other soil samples of the area the carbonate content is high. It is fairly rich in nitrate content which increases with the depth, and has only a meagre supply of chlorides. The pH value varies between 8·0 and 8·5.

2. *Sandy Plain Areas*

Here the soil is brown in colour and sandy in texture. The humus content of the soil is very low when compared with that of the farm soil. The soil is porous and hence its capacity for retaining water is also very little. The carbonate content is nil. There is a good amount of nitrate. The chloride content is again very low. The pH value ranges between 4·0 and 7·5. There is very little base deficiency in these soils.

3. *Embryonic Dune Areas*

The soil is sandy and brown in colour. Water retentivity is very low with little or no humus content. The carbonate content of this soil is greater than that of the farm soil and the sandy plains. Nitrate content is considerable. The chlorides are in greater quantities. Base deficiency is little. The soil has a pH ranging from 4·0 to 8·5.

4. *Barchanoid Dune Areas*

Here also the colour of the soil is brown and it is sandy in texture. Humus content is very small. The capacity for retaining water is also negligible. The soil possesses negligible amount of carbonate. Nitrate content is moderate with little chloride. Base deficiency is very little. The pH value ranges between 4·0 and 7·5.

5. *Stabilized Dune Areas*

The upper layers of these soils are usually blackish brown with lot of humus in them. The deeper layers are brown in colour. The

texture of the soil is sandy. It does not have a good supply of carbonates but the nitrates are in appreciable quantities. Chloride content is comparatively small. The base deficiency is low. The pH value ranges between 4·0 and 7·5.

In brief the soil of the area shows little base deficiency and contains appreciable amounts of nitrate. It is usually sandy and thus has got very little capacity to retain water. Carbonates and chlorides are meagre in the soil. The pH value ranges from 4·0 to 8·5.

Biotic Factors

The biotic factors that influence the vegetation of the area under survey are being dealt with in two categories since some of the areas are enclosed while some are not. The unenclosed areas are subjected to the usual biotic factors such as grazing cattle and sheep. The other mammals which try to disturb the climax vegetation are rodents and especially rabbits. Among the birds, peacocks and patridges play a significant role. The mammals and peacocks being fond of tender shoots do not allow the seedlings to develop fully which cause considerable damage to the herbaceous vegetation. Again the vegetation is sometimes locally cleared for construction purposes. The ground vegetation may be scraped exposing the loose soil to rapid erosion. Felling trees for timber and fuel, lopping the tops for fodder and pulling out herbs and annuals for medicinal purposes are practices which disturb the vegetation considerably. Locust swarms, needless to say, when they invade, cause a great havoc to the plant life. In addition to the disturbances caused by the above agents, pathogenic fungi, termites, caterpillars, etc., are other agents which affect the vegetation.

In the enclosed areas the usual biotic factors like grazing cattle or sheep are eliminated but the other biotic factors play their role here also.

Vegetation

The vegetation occurring in the area under study can be classified into two ecological groups of desert plants—the one the existence of which depends directly upon rain—the ephemerals; and the other which is sustained by subterranean water also—the perennials. From the foregoing environmental details it is observed that the vegetation is usually subjected to unfavourable conditions for most part of the year with the result that there is seldom any luxuriant growth. It is only during the rainy season that we find some greenary all around for a while which soon perishes after a short period. The vegetation in Pilani and its neighbourhood occurs in discontinuous patches of plant associations. According to the classification of the whole area under different categories of land, the vegetation is described separately for each type as the plant cover varies from place to place.

1. *Loamy Hard Soil Areas*

This type of soil is found in patches at a few scattered places. It usually supports extensive stands of either *Capparis* or *Zizyphus* or

TABLE II

Characters of the Soil Samples in Pilani and its Neighbourhood Areas from Different Directions and Localities and at Different Depths

Locality	Month and Year	Depth in cm. at which soil sample is taken	Colour of soil	Texture of soil	Carbonate content	Nitrate content	Chloride content	Reductivity	pH value
1. Cultivated field areas ..	Aug. 1952	7·5	Brownish Block	Sandy	++	++	+	++	8·5
	Sept. 1952	7·5	do.	do.	++	+++	++	+	8·0
	Nov. 1952	7·5	do.	do.	++	++	++	+	8·0
	Feb. 1953	7·5	do.	do.	+	+++	++	–	8·0
		15·0	do.	do.	+	++++	++	+	8·0
		22·5	do.	do	++	++ ++	++	+	8·0
		30·0	do.	do.	+	++++	+	–	8·5
		30·0—60·0	Brownish	do.	+	++++	++	–	8·5
2. Agricultural farm areas	Aug 1952	7·5	Brownish Black	Sandy	++	+++	++	++	8·5
	Sept. 1952	7·5	do.	do.	++	++++	++	+	8·0
	Nov. 1952	7·5	do.	do.	++	+++	+	–	8·0
	Feb. 1953	7·5	do.	do,	+	++++	+	–	8·5
		15·0	do.	do.	++	++++	++	–	8·0
		22·5	do.	do.	++	++++	+	+	8·0
		30·0	do.	do.	+	++++	++	+	8·5
		30·0—60·0	do.	do.	+	++++	++	–	8·5

3. *Sandy plain areas*	..	954	7·5	Brown	Sandy	–	+++	+	5·0
			15·0	do.	do.	–	++	+	6·0
			22·5	do.	do.	–	+	+	5·0
			30·0	do.	do.	–	++	–	7·5
			7·5	do.	do.	–	+	+	7·5
			15·0	do.	do.	–	+++	+	5·5
			22·5	do.	do.	–	+	–	5·5
			30·0	do.	do.	–	+++	–	5·0
			7·5	do.	do.	–	++	+	4·0
			15·0	do.	do.	–	+	–	5·5
			22·5	do.	do.	–	+	+	5·5
			30·0	do.	do.	–	+++	+	5·5
			7·5	do.	do.	–	++	+	5·5
			15·0	do.	do	–	+++	+	5·5
			22·5	do.	do.	–	+++	+	5·0
			30·0	do.	do.	–	++	+	5·5

TABLE II (*Contd.*)

Locality	Month and Year	Depth in cm. at which soil sample is taken	Colour of soil	Texture of soil	Carbonate content	Nitrate content	Chloride content	Reductivity	pH value
4. *Embryonic dune areas* ..	1954	7·5	Brown	Sandy	−	++	+	−	6·5
		15·0	do.	do.	+	+++	++	+	7·5
		22·5	do.	do.	−	+++	++	−	7·0
		30·0	do.	do.	−	+++	++	+	6·5
		7·5	do.	do.	−	++	++	+	6·5
		15·0	do.	do.	−	+++	+++	++	4·0
		22·5	do	do.	−	+++	+++	−	6·5
		30·0	do.	do.	−	++++	++	−	6·0
		7·5	do.	do.	+	++++	++	−	7·5
		15·0	do.	do.	+	+++	++	+	7·0
		22·5	do.	do.	−	++	+	+	6·5
		30·0	do.	do.	+	+++	++	+	6·0
		7·5	do.	do.	++	++	++	+	7·5
		15·0	do.	do.	+++	++	++	+	8·5
		22·5	do.	do.	+	+++	+++	−	8·5

5. *Barchanoid dune areas* ..	1955	7·5	Brown	Sandy	–	++	+	–	7·0
		15·0	do.	do.	–	++	++	–	6·5
		22·5	do.	do.	–	++	+	+	7·0
		30·0	do.	do.	–	++	++	–	7·0
		7·5	do.	do.	–	++	+	+	7·0
		15·0	do.	do.	–	++	+	+	7·0
		22·5	do.	do.	–	++	++	+	7·5
		30·0	do.	do.	–	+++	++	+	7·5
		7·5	do.	do.	–	+++	+	+	7·0
		15·0	do.	do.	–	+++	+	–	4·0
		22·5	do.	do.	–	+++	++	+	5·5
		30·0	do.	do.	–	+++	+	+	7·5
		7·5	do.	do.	–	++	+	–	7·0
		15·0	do.	do.	+	+++	++	–	6·0
		22·5	do.	do.	–	++	++	–	7·0
		30·0	do.	do.	–	+++	++	–	7·5

TABLE II (*Contd.*)

Locality	Month and Year	Depth in cm. at which soil sample is taken	Colour of soil	Texture of soil	Carbonate content	Nitrate content	Chloride content	Reductivity	pH value
6. Stabilized dune areas ..	1955	7·5	Blackish Brown	Sandy	–	+++	++	–	7·5
		15·0	do.	do.	–	++++	+	–	6·5
		22·5	do.	do.	–	+++	+	–	4·0
		30·0	do.	do.	–	++++	++	–	4·0
		7·5	do.	do.	–	++++	++	–	7·0
		15·0	do.	do.	–	++++	++	–	6·0
		22·5	do.	do.	–	+++	+	+	7·0
		30·0	do.	do.	–	+++	+	–	4·0
		7·5	do.	do.	–	++++	++	–	7·5
		15·0	do.	do.	–	++	++	–	6·5
		22·5	do	do.	–	+++	++	+	6·5
		30·0	do.	do.	–	++++	+	+	4·0
		7·5	do.	do.	–	+++	++	+	7·0
		15·0	do.	do.	–	+++	++	+	7·0
		22·5	do.	do.	–	+++	++	+	7·0
		30·0	do.	do.	–	++++	+	+	4·0

Salvadora. Associations of *Capparis* and *Zizyphus*, *Capparis* and *Gymnosporia*, and *Capparis*, *Zizyphus* and *Balanites* are also common. The ground cover during the rainy season consists of plants like *Doratanthera linearis* Benth. (d), *Commelina benghalensis* L. (c), *Fagonia cretica* L. (a), *Tephrosia purpurea* Pers. (c), *Heliotropium strigosum* Willd. (c), *Pupalia lappacea* (Linn.) Juss (c), *Trianthema crystallina* Vahl. (c), *Euphorbia clarkeana* Hk. f. (c) and *Trianthema decandra* Linn. (c). During the winter the new plants to invade the area include *Argemone mexicana* L. (d), *Achyranthes aspera* L. (c), *Mollugo hirta* Thunb. (a), *Polygonum plebejum* Br. (c).

2. *Sandy Plain Areas*

In such areas it is only after the first few showers that the sand is rendered less mobile. This gives the embedded seeds a chance to germinate. The early colonizers are *Tephrosia purpurea* Pers. (d), *Mollugo cerviana* Ser. (co. d), *Mollugo nudicaulis* Lamk. (a), *Crotalaria burhia* Ham. (a), *Borreria hispida* (L.) Schum. (c), *Trianthema decandra* L. (r), *Bærhaavia diffusa* L. (a), *Gisekia pharnaceoides* L. (c), *Calotropis procera* Br. (r), *Citrullus colocynthis* Schrad. (c), *Farsetia jacquemontii* Hk. f. and T. (a); *Gynandropsis pentaphylla* D.C. (c), *Portulaca oleracea* L. (r), *Digera enuricata* (L.) Mart. (r); *Polygala erioptera* D.C. (r); *Doratanthera linearis* Benth. (r); *Polycarpæa corymbosa* (L.) Juss. (c); *Tragus biflorus* Nees. (c), *Eragrostis ciliaris* Link. (c); *Cenchrus setigerus* Vahl. (a); *Eragrostis tremula* Hochst. (c); *Indigofera argentea* L. (c); *Corchorus trilocularis* L. (c); *Phyllanthus maderaspatensis* L. (c); *Leptadenia pyrotechnica* (Forsk.) Decne. (c); *Saccharum munja* Roxb. (c); *Convolvulus pluricaulis* choiss. L. (c); *Tribulus terrestris* L. (r); *Amarantus viridis* L. (c); *Heliotropium strigosum* Willd. (c); *Justicia procumbens* L. (c). During the winter season, only plants like *Tephrosia purpurea* Pers., *Crotalaria burhia* Ham., *Aerua tomentosa* Forsk. persist. The new plant invading the area in the season is *Argemone mexicana* L. which soon becomes a dominant species, while plants like *Justicia simplex* D. Don. (c), *Doratanthera linearis* Benth. (c); *Fagonia cretica* L. (a); and *Psammogeton biternatum* Edgew. are fairly well represented. The other plants of the area are *Prosopis spicigera* L. (a); *Acacia arabica* Willd. (c), *Balanites ægyptiaca* L. (r), *Gymnosporia spinosa* (Forsk.) Fiori. (c), *Acacia Jacquemontii* Benth. (c), *Zizyphus nummularia* Wt. and Avn. (c), *Ephedra foliata*, var. *ciliata* Boiss.

In the cultivated areas of the sandy plains, rainy-season crops like *Pennisetum typhoidium* Rich., *Phaseolus mungo* L., *Cicer arietinum* L., *Sorghum vulgare* Pers., *Zea mays* L., etc., etc., are grown. In addition to this, various *Cucurbits* are also grown. Sometimes *Crotalaria juncea* L. is also cultivated. In the cultivated fields *Trianthema monogyna* L. grows profusely as a weed.

3. *Sand-Dune Areas*

(*a*) *Embryonic Dune Areas*.—These are of varying size and shape depending upon the configuration of the place and the direction of the wind. With the rains the plants of the season begin to sprout. The

early colonizers are *Mollugo cerviana* Ser. (d), *Aerua tomentosa* Forsk. (co. d), *Crotalaria burhia* Ham. (*a*), *Farsetia jacquemontii* Hk. f. and T. (*c*); *Justicia procumbens* L. (c); *Tephrosia purpurea* Pers. (c); *Bærhaavia diffusa* L. (c), *Trianthema decandra* L. (r); *Borreria hispida* (L.) Schum. (c); *Euphorbia clarkeana* Hk. f. (c); *Polygala abyssinica* Fresen. (c); *Polycarpæa corymbosa* Lam. (a), *Doratanthera linearis* Benth. (c); *Phyllanthus maderaspatensis* L. (c); *Gisekia pharnaceoides* L. (c); *Cenchrus setigerus* Vahl. (c); *Tragus biflorus* Nees. (*c*); *Heliotropium strigosum* Willd. (c). During the winter *Tephrosia purpurea* Pers., *Crotalaria burhia* Ham. and *Aerua tomentosa* Forsk. persist. *Argemone mexicana* L. comes up at this time and soon becomes a dominant plant.

(*b*) *Barchanoid Dune Areas.*—The areas having such types of dunes usually do not support a very thick vegetation. Due to the prevailing winds in the locality, hardly any plant can grow. However, seeds which are carried by the wind towards the windward slopes of the dune are capable of germinating. As already stated in the foregoing pages, the slope of the dune usually faces towards the east and it is on that side that more plants are found. It has also been observed that they grow either on the slope or at the base of the slope or in the space between the arms of the Barchan or in between two Barchanoid dunes. The early colonizers on this side are *Crotalaria burhia* Ham. (d), *Aerua tomentosa* Forsk. (co. d), *Calotropis procera* Br. (r), *Bærhaavia diffusa* L. (c), *Cenchrus setigerus* Vahl. (c); *Farsetia jacquemontii* Hk. f. and T. (c); *Mollugo cerviana* Ser. (a); *Citrullus colocynthis* Schrad. (r); *Cyperus arenarius* Retz. (c); *Gisekia pharnaceoides* L. (c). At the top of the dune, the plants that grow are *Calotropis procera* Br. (c), *Saccharum munja* Roxb. (c), *Zizyphus nummularia* Wt. and Arn. (c), *Bærhaavia diffusa* L. (c), *Aerua tomentosa* Forsk. (c), *Mollugo cerviana* Ser. (a) and *Tephrosia purpurea* Pers. (r). By the middle of November most of the rainy season plants die out, leaving the harder perennials. The new species that enters the area is *Argemone mexicana* L. which soon become dominant. The other plants of the area are *Prosopis spicigera* L., *Capparis decidua* (Forsk.) Pax., *Gymnosporia spinosa* (Forsk.) Fiori, *Lycium europium* L., *Clerodendron phlomidis* Linn. f.

(*c*) *Longitudinal or Seif Dune Areas.*—These dunes are usually stable as they support the growth of bushes like *Gymnosporia spinosa* (Forsk.) Fiori., *Lycium europium* L., *Clerodendron phlomidis* Linn. f., *Saccharum munja* Roxb., *Zizyphus nummularia* Wt. and Arn., *Capparis decidua* (Forsk.) Pax., *Calotropis procera* Br. etc. On the slopes, the chief plants of the rainy season are *Aerua tomentosa* Forsk. (d), *Bærhaavia diffusa* L. (a), *Crotalaria burhia* Ham. (co. d), *Gisekia pharnaceoides* L. (c); *Tephrosia purpurea* Pers. (c), *Cenchrus setigerus* Vahl. (c); *Corchorus æstuans* L. (c), *Leptadenia pyrotechnica* (Forsk.) Decne. (c). In addition to these, shade loving plants like *Commelina benghalensis* L., *Pupalia lappacea* (Linn.) Juss. and *Vernonia cineria* Less. also occur. During winter *Argemone mexicana* L. becomes the dominant species.

(*d*) *Sand Mound Areas.*—These usually support the bushes of *Lycium europium* L., *Gymnosporia spinosa* (Forsk.) Fiori., *Capparis*

decidua (Forsk.) Pax., *Zizyphus nummularia* Wt. and Avn. On the open sandy areas species like *Mollugo cerviana* (d), *Gisekia pharnaceoides* L. (c), *Corchorus æstuans* L. (c), *Cenchrus setigerus* Vahl. (c), *Crotalaria burhia* Ham. (a), *Tephrosia purpurea* Pers. (c), *Farsetia jacquemontii* Hk. f. and T. (c), *Justicia procumbens* L. (c), *Polygala erioptera* D.C. (r), *Polycarpæa corymbosa* Lamk. (c), *Aerua tomentosa* Forsk. (c), *Gynadropsis pentaphylla* D.C. (r) and *Phyllanthus maderaspatensis* L. (c) grow after the first showers. The shade loving plants like *Pupalia lappacea* (Linn.) Juss., *Commelina benghalensis* L. grow under the shade afforded by the bushes. During winter *Argemone mexicana* L. becomes the dominant species.

(*e*) *Stabilized Dune Areas.*—The stabilization has been brought about by *Capparis decidua* (Forsk.) Pax., *Gymnosporia spinosa* (Forsk.) Fiori., *Lycium europium* L., *Zizyphus nummularia* Wt. & and Arn. and *Calligonum polygonoides* L. In the shade just after the rains, profuse growth of *Riccia* species, mosses and other shade loving plants like *Tubiflora acaulis* O. Kuntze. (d), *Corchorus æstuans* L. (c), *Perotis hordeiformis* Nees. (a), *Eragrostis ciliaris* Link. (c), *Eragrostis tremula* Hochst. (c), *Eragrostis poæoides* Beauv. (c), *Bærhaavia repanda* Willd. (co. d) takes place. *Mollugo cerviana* Ser. which Bakshi (1954) rarely came across in the shady places, has been observed to grow under shade at so many places. After the rains, the slopes of these dunes on all sides support plants like *Mollugo nudicaulis* Lamk. (c), *Gisekia pharnaceoides* L. (c), *Corchorus asetuans* L. (c), *Tephrosia purpurea* Pers. (c), *Mollugo cerviana* Ser. (c), *Perotis hordeiformis* Nees. (a), *Tragus biflorus* Nees. (c), *Eragrostis ciliaris* Link. (c), *Tribulus terrestris* L. (r) and *Euphorbia microphylla* Heyne (c). During winter *Argemone mexicana* L. is dominant. Other plants represented are *Vernonia cinerea* Less. (c), *Psammogeton biternatum* Edgew. (a), *Launæa pinnatifida* Cass. (c) and *Sonchus oleraceus* L. (c).

Discussion

A cursory glance at the available literature shows that very little work has been done on the desert vegetation, and sand-dune vegetation in particular has been sadly neglected.

The whole area under study shows a strikingly worn-out and sand blasted topography with no important rivers except Katli. The biotic factors play a very great part in disturbing the climax vegetation. The soil of the area differs from locality to locality according to the categories of the land. The soils of typical sandy areas are found to be acidic in nature with appreciable amount of nitrate content. At the same time the soils of the cultivated areas, the sandy plains and of various types of sand dunes which are somewhat stabilized or are in the process of stabilization are alkaline in nature with plenty of nitrates. This usually helps in supporting a good vegetation. The climate of the area can be regarded as semi-arid. The blowing of strong and gentle winds and cross winds is a marked characteristic of the region. Moreover, the desiccating action of the wind and the erosion caused by the same are the processes playing intensively upon vegetation.

The vegetation in Pilani and its neighbourhood shows some very interesting features. The plant cover within the area is found in discontinuous patches of plant associations on different types of soils. Broadly speaking, it can be classified into two groups of plants—the ephemerals and the perennials. The ephemerals usually sprout after the first few showers and present a characteristic type of vegetation within the area. The pioneer species which bind the sand together and consolidate the soil are *Tephrosia purpurea* Pers., *Crotalaria burhia* Ham., *Aerua tomentosa* Forsk., *Leptadenia pyrotechnica* (Forsk.) Decne. and a few grasses. The dominance of all these plants varies from soil to soil. The other plants which are found growing within the area are *Capparis decidua* (Forsk.) Pax., *Prosopis spicigera* L., *Gymnosporia spinosa* (Forsk.) Fiori., *Calotropis procera* Br., *Acacia arabica* Willd., *Mimosa hemmata* Willd., *Zizyphus nummularia* Wt. and Arn., *Balanites ægyptiaca* L., *Salvadora persica* L., *Ephedra foliata* Boiss., *Saccharum munja* Roxb., *Lycium europium* L., *Clerodendron phlomidis* Linn. f. and *Calligonum polygonoides* L. The dominance of these plants also varies from locality to locality. Usually extensive formations of a single plant or of a mixed type are observed. Extensive stands of either *Capparis decidua* (Forsk.) Pax. or *Capparis*, *Zizyphus*, *Balanites* or *Capparis*, *Gymnosporia* are very common within the area. A very important and characteristic association of *Calligonum polygonoides* L., typical of the arid desert tracts has been noticed near the village of Khundanio, a place which is at a distance of nearly 6·5 km. from Vidya Vihar.

The root systems of ephemerals have been found to be both shallow and deep. A few ephemerals have been observed to possess quite deep root systems. The perennials are very characteristic in this sense and have very long deeply-seated root systems. It is only due to this deep root system that the perennials are able to persist here, even during the arid summers since they are able to exploit the subsoil water fully. Another characteristic feature of importance is that a few of these plants have been noted to show flowering and fruiting at that period of the year.

The bushes present within the area play a very important role, as they act as obstacle in the path of moving sand grains and trap them. At the same time they greatly reduce the wind velocity so that grains are not carried farther. Afterwards these are consolidated by the root systems of the plants already growing on the spot. The plants thus grow and die off adding humus content to the substrata season by season and year by year. The addition of humus considerably improves the soils for plant growth. This can hold good for the sandy soils, since the humus colloids when present have got the power to retain more water. This results in the plants being less affected by the wind erosion to which the dunes are subjected and being less liable to destruction.

The vegetation seems to be a *Prosopis Capparis Climax association*, characteristic of the semi-desert regions capable of growing into a firm and closed type.

Summary

1. A preliminary report of the sand-dune vegetation of Pilani and its neighbourhood is submitted.

2. Location and topography of the area under consideration have been described.

3. Environmental factors like climate, physiography, soil and biotic influence are given.

4. The existing vegetation growing within the area is in discontinuous patches of plant associations which vary from patch to patch and give the region the appearance of a typical scrub jungle. A brief account of the plants growing on different types of dunes and soils has been given.

5. No definite ecological status can be assigned to the vegetation of the area until the study is complete, but at present the existing vegetation seems to be a *Prosopis Capparis Climax association.*

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ANNOUNCEMENT

The Ninth International Botanical Congress will be held in Montreal, Canada, from August 19 to 29, 1959, at McGill University and the University of Montreal. The program will include papers and symposia related to all branches of pure and applied botany. A first circular giving information on program, accommodation, excursions, and other detail will be available early in 1958. This circular and subsequent circulars including application forms will be sent only to those who write to the Secretary-General asking to be placed on the Congress mailing list:

DR. C. FRANKTON,
Secretary-General,
IX International Botanical Congress,
Science Service Building,
Ottawa, Ontario,
Canada.